ENGINEERING

An Illustrated Weekly Journal

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UNIVERSITY OF MICHIGAN

ENGINEERING

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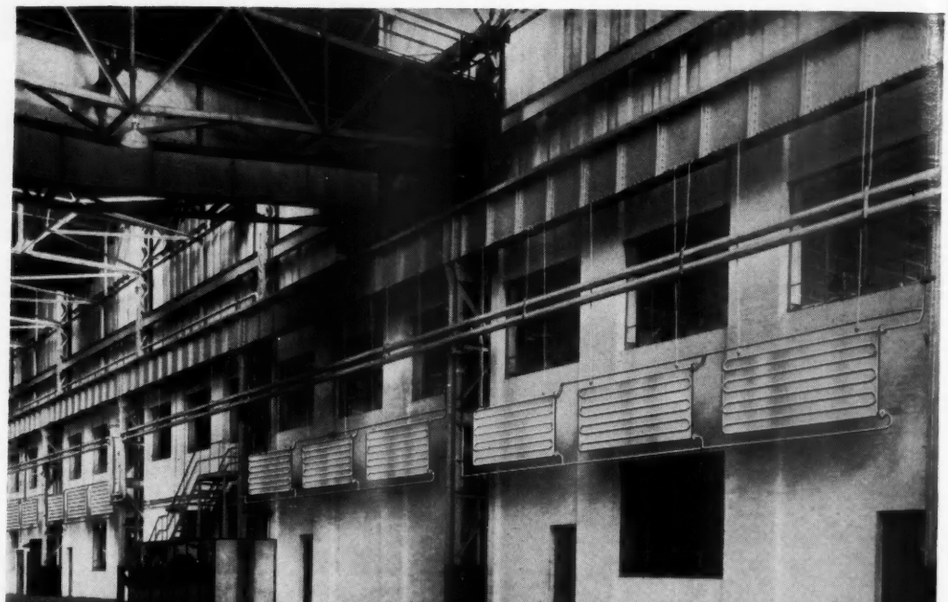

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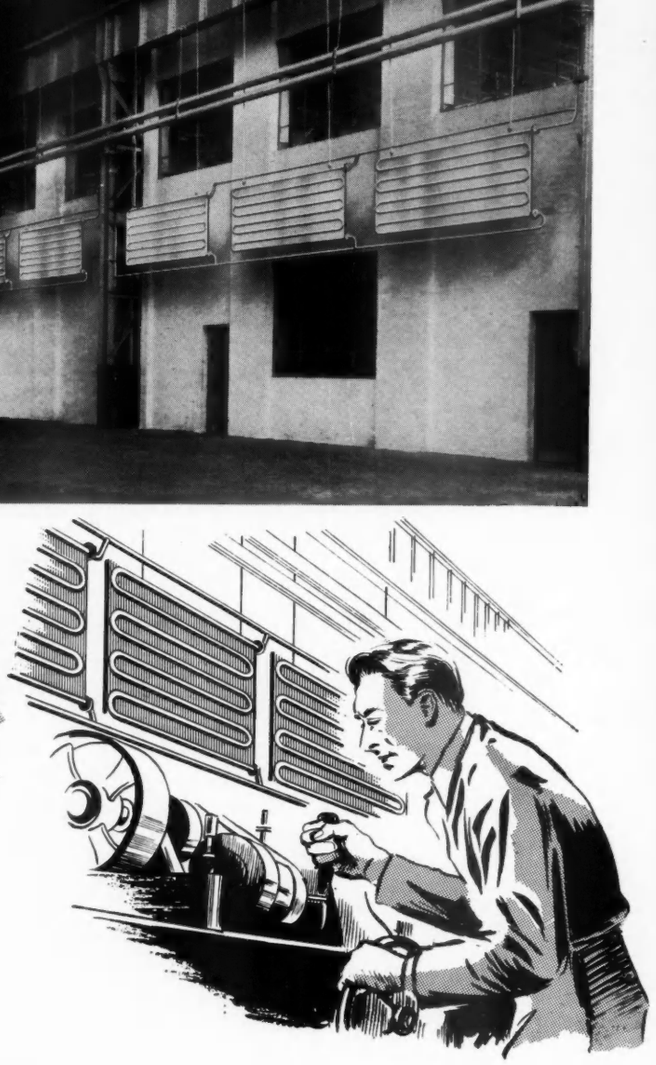

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ENGINEERING

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INDEX TO "ENGINEERING"

Volume 180 now ready

The Index to Volume 180 (July-December, 1955) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher, 35 and 36 Bedford-street, London, W.C.2. Any reader wishing to receive regular copies of the Index as they are published can apply to be put on the mailing list. Those already on the mailing list need not re-apply.

JOBS FOR YOUTH

MOST engineers to-day are doing rather more than one man's job. How many more will be required, in each industry, within the next three years? And the new recruits from universities and technical colleges—which industries will offer them the greatest opportunities? These are vital questions affecting everyone in the profession, and for the first time "official" answers are available.*

An increase of 30 per cent. in the number of engineers required throughout the country is forecast for 1959. That is the overall picture. Some industries will require more, some less. And the various branches of the profession are expected to differ in their rate of growth. Thus, for example, the need for chemical engineers is likely to go up by 47 per cent. Other branches which will grow faster than the 30 per cent. average are metallurgists (classified as engineers for this purpose) and mechanical engineers. But a slower than average increase is expected for electrical engineers, civil engineers, mining engineers, and engineers engaged in teaching.

Take a look now at some specific industries: what they are planning and how they compare with each other. Electrical engineering is by far the largest employer of engineers and scientists (figures are not given separately for engineers and scientists), accounting for over 12,000. Adding the 5,800 who are with the electricity authorities gives a total of 18,000—which is a substantial proportion of the 120,000 covered by the survey. The electricity authorities do not envisage a big increase by 1959, but the electrical engineering manufacturers hope to employ 43 per cent. more. The increase will be accounted for, however, much more by mechanical than electrical engineers. Whichever way the electrical manufacturers are examined they are clearly among the leaders in their use of qualified men. Though the average employment of engineers and scientists in manufacturing industry is equal to 0·8 per cent. of the total employees, these firms average 2·0 per cent. And there are nearly twice as many engaged in research and development as there are in manufacture, production, operation, maintenance and installation, compared with about equal numbers in industry generally. The electrical manufacturers at present have a quarter of all engineers and scientists in manufacturing industry.

The nationalised industries, taken together, have about the same ratio of scientists and engineers to total employees as the manufacturers, but if we leave out the Atomic Energy Authority the picture is not nearly so good. For example, the Transport Commission, with a larger labour force than any industry except the Coal Board, has only 172 qualified people on research and development, compared with 1,015 on operation, maintenance, etc. Considering the great extent to which British Railways carry out their own design and production, the figure of 172 on research and development is ludicrous. The Transport Commission envisage an increase of 31 per cent. in their engineers and scientists by 1959, but it is extremely doubtful whether this will be sufficient to make up for past neglect and the demands of the modernisation plan. Clearly, engineers on the railways are going to be overloaded with work.

Does a very small proportion of engineers in an industry indicate golden opportunities for newcomers, or a feeling among the leaders of the industry that there is not much work for them to do? For example, in two major industries—shipbuilding and motor vehicles—the figure is only 0·4 per cent. In the whole of the shipbuilding industry there are only 69 qualified people on research and development, and the increase envisaged by 1959 is relatively small. Even the food, drink and tobacco firms have 426 on research and development. Among the manufacturers who plan to employ a much greater number of engineers and scientists in the next three years are those engaged in oil refining, aircraft, precision instruments (the greatest increase of all—60 per cent.), cotton, clothing, and the group which includes wood, cork, paper and printing.

The requirements for three years hence were computed from information supplied by industry. Looking farther ahead, the committee on scientific manpower use an interesting approximation (borne out by past experience)—that the ratio of the increase in numbers of scientists and engineers employed to the increase in industrial output is about 1 to 1. The committee also worked on the assumption that there will be an average increase of industrial production at the rate of 4 per cent. per annum. Such consideration of long-term requirements leads to the conclusion that there will have to be an increase of 70 per cent. in the number of engineers in this country, and a 50 per cent. increase in scientists, in the next ten years. By 1970 the annual output of qualified people should be doubled. This target should not be impossible; the universities have already passed the goal set by the Barlow committee after the war. At the present time the engineers and scientists of Britain represent only 0·6 per cent. of the working population. Their numbers must be raised; too much depends on too few.

* *Scientific and Engineering Manpower in Great Britain.* H.M. Stationery Office (1*s.* 6*d.*)

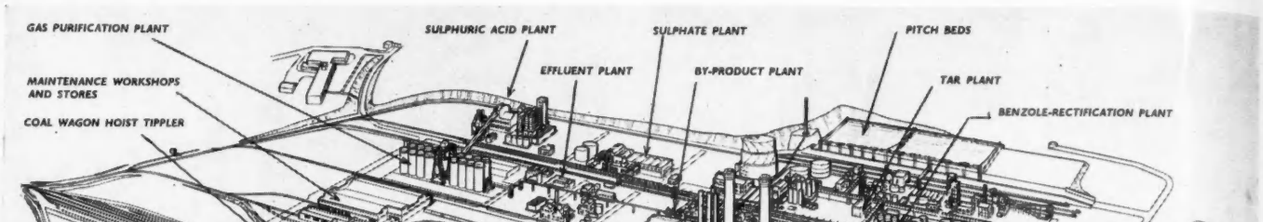

Fig. 1 The Avenue carbonisation plant is designed for flexibility. The products can be varied to suit market conditions, and raw materials are reduced to a minimum.

Plain Words

Mechanics, engine drivers, firemen, turners, drillers, riveters, steel erectors, oilers, greasers, welders, boilermen, platers, linesmen, electricians and many others who have their own correct descriptions enjoy at some time or other the title of engineer. Many of them, it is true, are well trained and, in the words of a memorandum, issued by the senior institutions, are well able to apply in a responsible manner proven techniques and understand the reasons for, and the purposes of, the operations of which they are in charge. Many, moreover, are responsible for extensive and complex plant and some supervise large and diverse staffs. For those who are so qualified, the institutions have for some years pressed for the adoption of the very satisfactory term "technician." Sir Harold Bishop, in his recent presidential address to the Association of Supervising Electrical Engineers, gave his support to the use of the term, and recommended his hearers to accept it as being a title fairly descriptive of themselves and " without any of the slightly derogatory impression which it apparently conveys to some."

The loose application of the title of engineer has persisted in Britain—though not everywhere abroad—for too long for there to be much chance that those fully entitled to the term should ever come to enjoy it as a privilege. There is not, however, much to be said for some of the alternatives that have been proposed as a designation for corporate members of the chartered institutions. That machine watchers and chaps whose only tool is a spanner should be called engineers is bad enough. But that engineers should be lumped together with that amorphous group termed scientists and the combination denoted by that ugly appellation " technologist " is a change that only makes confusion worse. What are engineers?—only engineers seem to know.

COAL AS A RAW MATERIAL

BALANCED ECONOMIES IN AN INTEGRATED CARBONISATION PLANT

Integration and self-sufficiency are the themes behind the construction of the National Coal Board's Avenue carbonisation plant, near Chesterfield. Based on the theory that coal is a raw material rich in hydrocarbons, equal weight is given to the various end products—sulphur, benzole, gas, coke and many others. The flexibility of the layout is such that alternative fuels can be used in several stages, so that full advantage can be taken of the market value of the products.

The site was selected for accessibility by rail, and utilises a connection for a former colliery. It covers 188 acres. The present capacity is for 2,175 tons of coal a day, but the whole layout has been planned for a future extension to double this figure. The main contractors who were responsible for the whole of the site preparation and the greater part of the plant were Woodall-Duckham Construction Company, Limited, 63-77 Brompton-road, London, S.W.3. Initial plans were made in 1948 when it was realised that two plants in the East Midlands Division of the National Coal Board would have to be closed, and three more were rapidly becoming obsolete. The Carbonisation General Manager of the East Midland Division, Mr. G. W. J. Bradley, has followed the scheme through from the beginning. Great attention has been paid throughout to avoid atmospheric pollution. Rail trucks are handled by five Diesel locomotives over the 13 miles of track, under radio directions from a central station.

COAL HANDLING

Coal for the plant is received by rail, and is drawn from a number of local collieries which can supply large quantities of the lower-ranking carbonising coals, rather rich in sulphur. The wagons are discharged by a Mitchell double tippler, each side of which can handle thirty 24 ton wagons per hour. Wagons run to the tippler by gravity, and when empty are run off at a higher level so that gravity is again used to take them to the empties sidings. Belt conveyors, with a capacity of 400 tons per hour, take the coal first to a preliminary crusher (if required) and then to the eighteen main storage bunkers. These have a total capacity of about 20,000 tons and are arranged in two rows of nine, with an overhead conveyor feeding each row. Reinforced concrete structures, they were built by continuous racking, the shuttering being lifted 1 in. per hour by climbing jacks. Conveyor belts run below each row and coal is fed to them from each bunker by Sherwen vibrating tray feeders. As each feeder is under separate control, accurate blending of different grades of coal stored in different bunkers is possible, so that the final properties of the coke and other products can be controlled. Fig. 3 shows the bunkers, and shows also how easily they can be extended when required.

The blended coal passes through British Jeffrey-Diamond hammer pulverisers which reduce it in size so that 80 per cent. will pass ⅛ in. square screen. Another series of conveyors then takes it to the ovens bunker. This is approximately 150 ft. high and has a capacity of 4,000 tons with a separate compartment of 800 tons for experimental work. Coal from the 20 hand operated gates is fed to the two Buchanan charging cars which run on rails along the top of the ovens. One is visible in Fig. 4 (page 548). Each of the cars, which are electrically propelled, has four steel hoppers with a total capacity of about 16 tons—the charge for one oven. Each hopper is fitted with electrical vitrabors, an adjustable measuring device and a telescopic spout, which last is electrically interlocked with the travelling motor so that the car cannot be moved with a spout extended. A Pooley weighbridge of 60 tons capacity fitted with a dial indicator and recorder, weighs the coal in the car before discharge.

UNDERJET OVENS

A battery of 53 ovens is arranged on each side of the ovens storage bunker, and the two 250 ft. stacks are centrally located on the west side of the bunker. The Woodall-Duckham Becker Combination Underjet type oven has

been used and each measures 41 ft. 1¼ in. between the doors and 13 ft. in height, with an average width of 16 in. In each a charge of about 16 tons can be carbonised in approximately 15 hours, the temperature at the centre being 850-900 deg.C. when it is pushed out. Heating can be either by coke-oven gas, or by producer gas generated in a separate plant. The system is arranged to direct the flame up one side of the oven, across the top and down the other, the direction of flow being automatically reversed every half hour. Below each series of flues are two regenerators, each divided down the middle into two sections of half-oven length. Recessed bricks are used at the bottom of these to form channels from which any dust deposited from the gases can easily be removed. When producer gas is used for firing, both gas and air are separately heated and meet in a streamline flow at the bottom of the vertical flues where combustion begins. Only the air is heated when coke-oven gas is used.

SELF-SEALING DOORS

The oven doors are self-sealing and are of the design developed by the Koppers Company, Pittsburgh, U.S.A. The gas-tight seal is obtained by the contact of the knife edge of a steel sealing ring with the faced door jamb. Self-adjusting spring-loaded plungers maintain the contact. The doors hang from a self-centring shelf at the top of the jamb and are held by screw-operated latches. The operation of each battery is controlled from a separate room.

For discharging the coke there are two pusher machines of Buchanan manufacture, following the designs of the Koppers Company. One can be seen in Fig. 4. They travel the length of the batteries. The pushing ram is of lattice design and welded construction with a cast-steel head. It is rack and pinion driven and runs in a cast-steel supporting stool and shoe. The leveller bar is of welded steel and is rope driven. Any coal that falls out during the levelling process is caught by a hopper on the pusher carriage, from which it can be discharged when required into a bucket and so returned by an electric hoist to the charging cars. The door extractor beam, which is rack and pinion driven, is fitted with worm-driven cast-steel arms which lift and lower the oven doors, and with planetary-geared latch tightening gear. The latter is fully compensated to allow for any inaccuracy in positioning. Separate motors are provided for each of the six operations. In an emergency due to a failure of the electric power the pusher ram can be withdrawn by a medium pressure steam engine and the leveller beam by hand gear. Each machine weighs about 130 tons and can be run on its rails direct to the workshop for maintenance.

The machines are fitted with a decarbonising device which enables air to be blown to the oven roof from a nozzle on the ram head. Air for this device is provided by an air compressor and storage tank mounted on the machine. The operator's cabin is fitted with a forced-draught ventilating system with a motor-driven fan which can also deliver air to the front of the machine for the operators during door cleaning operations for which a separate machine is provided.

COKE HANDLING

On the opposite side of the batteries run the two Buchanan quenching cars, each propelled by a Greenwood and Batley electric locomotive fed from overhead wires. Two Buchanan-built Koppers-design electrically operated door extracting machines with trailing coke guides of the racking type are provided to remove and replace the doors on the coke side, and to guide and support the hot coke over the coke side platform. The pusher machine and the discharge guide are electrically interlocked for positioning.

The quenching cars take the hot coke under an arch where a predetermined quantity of water is discharged over it. The water is returned to a settling sump and then recirculated by pumps. Breeze is extracted from the sump by a steam-powered grab crane. After quenching, the coke is discharged from the cars on to an inclined wharf where it can cool before passing through hand-operated gates on to a conveyor.

From the wharf conveyor, the coke is fed to the screening station, first over Gyron screen which separate it at 2½ in. and can be by-passed if desired, and thence to a series of screens which grade it into six sizes. These grades are stored in hoppers having a total capacity of about 500 tons. Each hopper has three outlets: one direct to rail wagons; one to the boiler house and producer plant by conveyor; and one, also by conveyor, to the land sale hoppers and bagging plant. Debreezing screens are fitted to each.

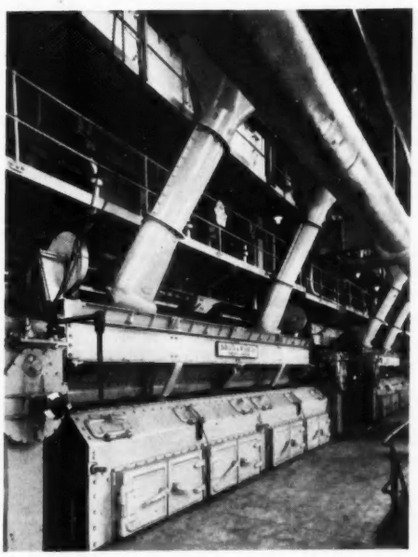

Fig. 2 Steam for all requirements is produced by three Babcock and Wilcox boilers, fired by coke breeze from the ovens.

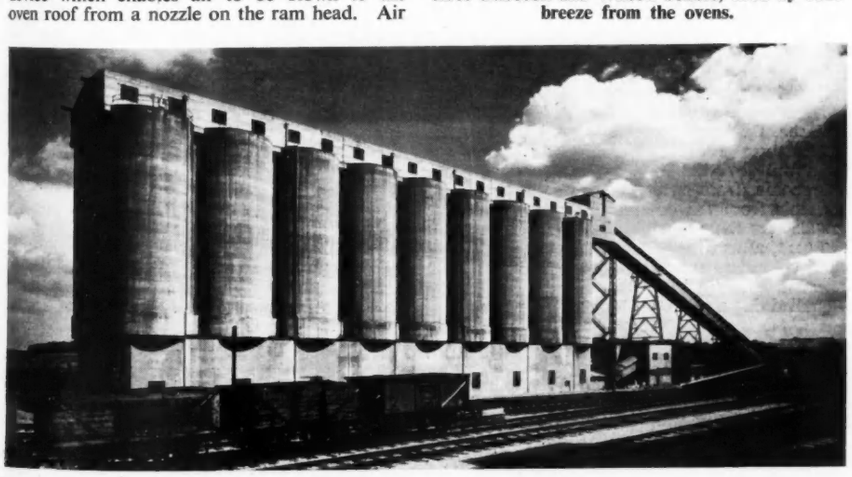

Fig. 3 Incoming coal is stored in 18 bunkers, according to grade. This enables chosen blend to be fed to the ovens to suit the end products desired.

GAS COLLECTING SYSTEM

The crude gas leaves the ovens through ascension pipes at both the pusher side and the coke side and passes into the gas collecting mains which are also on both sides of the batteries. On each battery a bridge pipe spans the battery at the centre and connects the pusher side and coke side collecting mains. To control the oven top temperatures each bridge pipe is provided with two 45 in. "Airscrew" fans which provide forced recirculation of the raw gas in alternate directions through the collecting mains and ovens. The reversal is automatically controlled.

The equipment included in the primary by-product plant is designed for the cooling and washing of the gas for the recovery of tar and ammonia liquor, the removal of naphthalene and the dilution and boosting of the purified gas available for distribution.

There are five primary coolers of the Whessoe multipass vertical water-tube type arranged to work in parallel with two coolers for each gas stream and the fifth as a common standby.

The condensate from the coolers is collected separately in two fractions, the condensate from the hot ends being returned via the hot condensate sump to the liquor flushing and separating tank, and that from the cold ends to the cold condensate sump from which the cold liquor gravitates to the strong ammonia liquor sump and the tar to the hot condensate sump. From the primary coolers the gas is passed by the three B.T.H. exhausters to the electro-detarrers.

TAR AND BENZOLE

Tar is extracted in four Whessoe Woodall-Duckham electro-detarrers and the gas then passes to four primary naphthalene washers of W. C. Holmes' design. It is then re-cooled in Whessoe multipass vertical condensers and passed to the six ammonia washers, which are identical to the naphthalene washers. Anthracene oil from the tar plant is used in the naphthalene washers and weak "fixed" liquor followed by soft water to remove the ammonia. The liquor can be bled from the flushing liquor main or taken from the crude benzole separators. Entrained moisture is extracted from the gas which then passes through the benzole scrubbers and the secondary napthalene washers.

Crude benzole is recovered by passing the gas through three scrubbers and distilling the wash oil. Carbon disulphide is removed in a separate column and is passed to a storage tank from which it can be loaded into road tankers. The benzole is then passed to the once-run column and the residue goes to the heavy naphtha column. Provision is made for receiving once-run benzole from other works for treatment in the rectifying plant. The heavy naphtha from the column passes through a condenser to a receiving tank and thence to the tar plant. The residue follows a similar course. From the rectification plant, motor spirit, toluol and all grades of benzole fractions including pure products can be produced.

The acid sludge from the benzole washers is treated with creosote and water, and agitated with steam. After settling, the acid is run off and the remaining creosote oil is further treated with soda and steam. The creosote then passes to the tar plant. Any benzole vapours are collected and recovered.

The ammonia liquor used for flushing the mains and in the washers is circulated by centrifugal pumps which can be either steam or electrically driven. There are two separating tanks from which scraper conveyors continuously

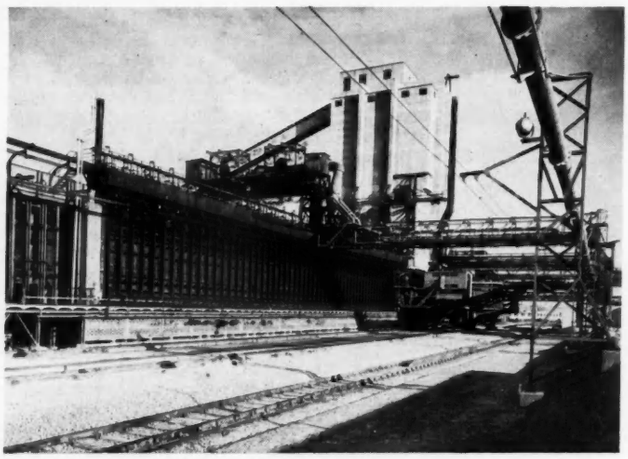

Fig. 4 The two banks of 53 ovens can be fired by coke-oven gas or producer gas.

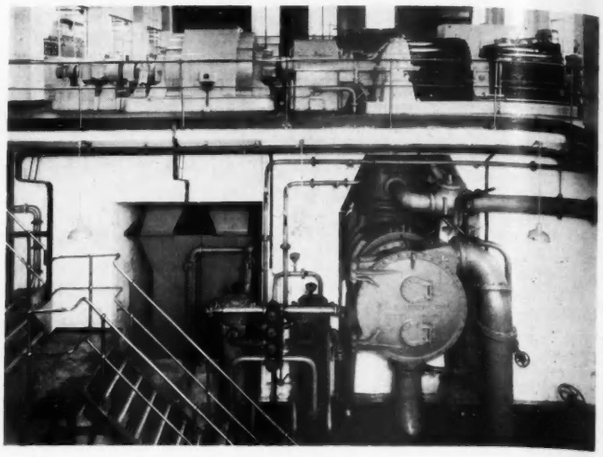

Fig. 5 Pass-out turbines supply power for electrical equipment and steam for process work in balanced proportions.

remove the sludge. A W. C. Holmes' oil regeneration plant treats the oil from the naphthalene washers, delivers a naphthalene-xylene oil fraction to the tar receiving tanks, and returns the stripped oil to the washers.

DRY GAS PURIFICATION

The next operation is dry gas purification carried out in a Newton Chambers plant. The process is based on the reaction between the hydrogen sulphide and a contact mixture of hydrated oxide of iron. The contact material is held in containers taking about 25 tons each, and stacked in towers up which the gas passes. Each of the two sets of towers has a stocking tower and a stocking frame in which containers of spent and fresh oxide respectively are placed. Handling is carried out by a Goliath travelling crane. The removal of spent oxide from a tower and its replacement with fresh can be accomplished in a few hours. The spent material is taken by conveyors to the sulphuric acid plant or else to a stocking area for shipment. The purified gas is pumped to a holder from which it can be withdrawn for heating the ovens or for sale to the local undertaking.

Dilution of the gas for sale is carried out by the addition of producer gas to give a calorific value of 480 B.Th.U. per cub. ft.

The ammonia liquor recovered from various stages of the plant, together with any brought in from outside, is passed to the sulphate plant for the production of ammonium sulphate. The plant has a capacity of 7,000 gallons per hour of liquor, which will produce about 45 tons of sulphate a day. The incoming liquor is stored in two tanks (from which tar is run off at intervals) and is then pumped to the ammonia stills. Alkaline water from the benzole plant is used to form the milk-of-lime required. The ammonia vapour is bubbled through sulphuric acid in a Royston saturator and two discharges lead to the crystal separation and centrifugal drying plant. Gas from the saturators is utilised in Royston heat exchangers working in conjunction with the ammonia stills. A conveyor removes the crystals for final drying and a pneumatic system takes them to the automatic bagging plant.

Tar from the different stages is collected in crude storage tanks and is then processed in a Wilton distillation unit. At present 200 tons per day is being handled to produce benzole, solvent naphtha, carbolic oil, naphthalene oil, creosote, anthracene oil and pitch residue. Acids are continuously extracted and stored, and naphthalene and anthracene are produced as oils or crystals. The pitch is piped to solidifying bays from which it can be mechanically retrieved as required and loaded on to wagons.

The Simon-Carves Kachkaroff acid plant extracts the sulphur from the spent oxide removed from the purifying towers and converts it to sulphuric acid. The spent oxide is fed to two Flixborough rotary burners at one end of the outer shell, where it immediately ignites. Oxide and cinder pass down between the shells to the other end where they are discharged through automatic doors. The gases produced pass inside the inner shell back to the feed end and are then conveyed to the acid plant, after having had any dust removed. The recovered oxide is mixed with peat and sawdust and can then be re-used in the purifying plant.

The furnace gases containing about 5 to 6 per cent. of sulphur dioxide, pass in turn through the concentration tower, the denitration tower, an atmospheric cooler and four reaction towers finally escaping to atmosphere through a filter tower. Acid flows in the reverse direction. In the towers the sulphur dioxide is converted first to sulphur trioxide and then to the acid. As the acid is formed it is bled off and pumped either to the ammonium sulphate plant or to rail tankers. P.V.C. has been used whenever temperature conditions permit, particularly for the reaction towers, which consist of P.V.C. sheets supported by an external wooden frame. The plant has a capacity of about 50 tons of 100 per cent. sulphuric acid per day.

ION EXCHANGE EFFLUENT TREATMENT

The effluent process plant has been designed by the Permutit Company, Limited, on the basis of the Corby process, developed by co-operative research with the Woodall-Duckham Construction Company, Limited, and Stewarts and Lloyds Limited.

A pilot ion-exchange plant erected at Corby steelworks was augmented by an activated-carbon plant and proved successful. It was from this plant that the Avenue equipment was designed. The plant removes thiocyanates and thiosulphates by the De-Acidite process and then concentrates them. Phenols and higher tar acids are removed by the activated carbon section. Ammonia from the De-Acidite flushing, and benzole from the carbon filters are recovered, as also are the phenols and tar acids. The final effluent, after treatment with lime, is innocuous and colourless and is discharged into the drain system. About 185,000 gallons of liquor are handled daily.

ENERGY SUPPLIES

Producer gas, sufficient to underfire one-third of the ovens and to dilute the surplus coke-oven gas, is produced from six Woodall-Duckham Koppers mechanical producers running on coke from the secondary screening station. The gas formed is cooled and dried and then stored in a single-lift holder. Ash is removed by skips which convey it to a hopper for subsequent delivery to rail wagons.

Steam for power generation and process work is supplied by three Babcock and Wilcox C.T.M. boilers, each rated at 60,000 lb. of steam per hour at 475 lb. per sq. in. and 640 deg. F. (Fig. 2). They are fired by coke breeze delivered from the screening plant. This is fed on to the twin travelling-grate stokers by two traversing chutes which give an even spread.

Electricity is generated by two W. H. Allen pass-out turbo-alternator sets, each rated at 5,000 kW (Fig. 5). The turbines have a high and low pressure cylinder in tandem and the steam is passed out between the two. Control is fully automatic. As a standby, or for starting up, a Diesel set of 500 kW is installed. Automatic interlocks start this set if the main system fails, and its output is sufficient to operate the circulating pumps and other vital items. Power is distributed to five sub-stations serving different parts of the works. A very considerable amount of power is required for the water cooling and recirculating equipment which has five separate systems. Raw water from a storage reservoir is treated and passed to a "clean" reservoir before being circulated round the plant. As re-circulation is the rule, only a comparatively small quantity of make up water is required.

OPERATING ECONOMICS

As was said at the beginning, integration and self-sufficiency are the theme of the whole plant. The only raw materials needed are the coal itself; peat and sawdust for the oxide regeneration; and lime for the ammonia stills. Sales products are coke in varying grades; town gas; sulphuric acid; ammonium sulphate; benzole in various grades; naphthalene; anthracene; creosote; tar; and pitch. A balance can be obtained between many of these to suit market conditions. For instance, by using more producer gas (made from coke from the ovens) to fire the ovens, more town gas can be sent out. Instead of the usual figure of about 14 million cub. ft. a day (out of the 27 million produced altogether) it can be increased to about 18 million. Again, if the market for pitch, should fall off, the operating temperature can be altered to yield a harder product which can be granulated and carbonised in the ovens with the coal. Similarly, the grades of benzole can be chosen. The fact that all the gas produced goes through the dry purification plant not only increases the yield of sulphur, but almost eliminates sulphureous fumes from the ovens.

Breeze from the ovens fires the boilers and by using pass-out turbines, the electricity needed can be generated more cheaply than it can be supplied from the grid. A power balance can also be achieved within the works as the greater part of the machinery, particularly the fans and pumps, can be driven either by steam or electricity. The power house superintendent can thus choose how much plant shall run on steam

and how much on electricity to balance the varying steam demands of the processes and maintain efficient use of the energy available.

Breeze and crude products can be brought by road from other carbonisation plants in the East Midlands division and processed at Avenue. To allow for this the chemical plant has been built to handle products from 4,500 tons of coal a day, and the output of sulphuric acid is sufficient for all other plants in the division. Constant regeneration of the oxide means that this does not have to be regularly replaced by fresh supplies —another saving of expense. The coke produced—about 1,400 tons a day—is sold partly to the domestic market and partly to industry, but the flexibility of the plant is such that the entire output can be changed to metallurgical coke in a very short period.

Letters to the Editor

VACATION EMPLOYMENT

SIR, I have recently been reading the essays that my students (of civil engineering) have written about their vacation employment and your readers may be interested in some of the thoughts that have been raised in my mind.

The first is one of gratitude to all the firms and organisations which, by employing these students, have played such a vital part in their education. Some firms, no doubt, look on these vacation jobs as a valuable way of selecting future staff or, perhaps, at a time when engineers are in short supply, of influencing future graduates to select them. Whether this was a relevant consideration or not, the responsible engineers and managers have, in many cases, obviously taken considerable personal trouble to give the students the best possible experience in the eight weeks or so that were available, in spite of the fact that in such a short time few students were able to learn enough to be really useful.

Students got most benefit and enjoyment from those jobs where they could forget their undergraduate status and, by working with their hands or brains, identify themselves completely with the firm. This can obviously be contrived more easily in some places than in others. One student worked with a maintenance gang in a chemical works and was soon accepted as one of the team; another laboured all through the summer mixing and laying concrete—not a very intellectual exercise, but one which gave him no little insight into the realities of construction work. These men were able, probably for the last time, to work on equal terms with artisans and thus to see the labour-management situation from below.

These were first-year students who had not then taken courses in surveying or design and who could not be fitted into a civil-engineering design office or construction job as easily as second-year men. Those employers who found it possible to give the latter a certain amount of responsibility, whether for a simple design or for some surveying or setting-out, would be gratified to find how enthusiastically such students described "their" work. I suspect that it is less easy, in a highly organised factory, to devise jobs for which a young mechanical engineer can be held completely responsible, but our experience in civil engineering shows that the effort is well worth while.

Those students who underwent a rather more formal "vacation apprenticeship," taking the form of periods of a week or so in the various departments of a big concern, were, on the whole, the least satisfied. It is perhaps insufficiently realised that undergraduates are accustomed to making observations and absorbing knowledge at high speed; such a man is probably able to get the hang of a department in a day or so and, unless he is actually participating in the work, will be bored before his week is out and he moves on.

Finally, it is sad to have to record the very great difficulty with which our coloured students find employment. To put it at the lowest level of national self-interest there is singularly little to be said for losing an opportunity of befriending young men who have come here for their technical education, especially when they will inevitably rise quickly to positions of influence and decision when they return to their own countries. Two further things should be said about this: the first is that the colour bar seems to be applied at management level and not by the working men on the job and the second is that, in my observation, the nationalised industries in general and the C.E.A. in particular are beyond reproach in this matter.

Yours faithfully,
J. A. L. MATHESON,
Professor of Engineering.

Engineering Department,
University of Manchester.
October 25, 1956.

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THE SHAPE OF THINGS

SIR, Is a catenary an organic or inorganic form ?

Yours faithfully,
D. B. WELBOURN.

Selwyn College,
Cambridge.
October 25, 1956.

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ARTS UNDERGRADUATES

SIR, The parting shot under "Plain Words" in your issue of October 12 is not, intrinsically, objectionable in that the reduction of the proportion of arts undergraduates from 45 per cent. to half this figure does not necessarily imply a reduction in the total number of arts undergraduates. It is surely not your intention that the Government should cut the numbers of arts undergraduates by forcibly trimming the arts faculties in the universities? Such a philistinic action would anyway be difficult to accomplish, since the suppression of a culture is no easier than its synthesis.

There would seem to be two advantages in this policy: (*a*) Lecture rooms, museums and libraries would become available for use in the teaching of the sciences—a ludicrously slight advantage when compared with the effort made by our ancestors to create the arts, even if this effort now seems to have been misplaced. (*b*) High-grade minds would have no outlet, except in the sciences, and would therefore become of greater use to the country—a dangerous assumption. The present ratio of arts to science undergraduates represents a form of public opinion which is not easily swayed and moreover should not be swayed by a mere Government.

If, on the other hand, it is your intention that the number of arts undergraduates should not be reduced, then the number of science undergraduates must be increased by no less than 180 per cent. I should be interested to have your proposals for carrying this out, without loss of quality, and "within a few years." I think it is obvious to all scientists and engineers that an increase in their numbers is necessary for the material welfare of the country. I must also say that your statement is unlikely to inspire an effort towards this, and indeed discredits the name of science.

Yours faithfully,
T. J. MURPHY.

12 Caxton-street,
London, S.W.1.
October 26, 1956.

Editor's note: Nine-tenths of the answer to Mr. Murphy's comment is to be found in the Government report on scientific and engineering manpower in Great Britain, which is the subject of our leading article this week. To quote: ". . . the number of people qualifying each year in science and engineering would need to increase from about 10,000 in 1954-55 to about 20,000 in 1970—an increase of about 100 per cent." It is highly improbable that the number of arts undergraduates will increase to a similar extent. The probability is, therefore, that the proportion they represent of the total university students will drop substantially. Whether the figure of 45 per cent. is halved remains to be seen. The change in emphasis, as between arts and science, will not be the result of "force" by the Government; it will be the result of a change in public opinion, aided by the fact that half the scientists of this country—25,610 out of 51,230—are engaged in teaching.

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SHEAR DEFLECTION IN SHORT BEAMS

SIR, The article "Shear Deflection in Beams," by Dr. R. P. N. Jones, in ENGINEERING for October 5, page 428, contains, I believe, two fundamental errors.

In the first place, it is stated that the slope of the neutral line due to shear is equal to the shear strain at the neutral axis. This is true only for special cases, such as thin-walled circular tubes, where there is no warping of the cross-section under the shear-stress distribution determined by the engineers' theory of bending. The correct area to associate with the deflection due to shear is best found from the consideration of the shear-strain energy. In the notation of Dr. Jones' article, the correct value of λ, the shape factor, for a rectangular beam is 1·2, whereas consideration of the shear strain at the neutral axis would give 1·5.

The second error is less obvious and concerns equation (11). This equation ought to read

$$F = V + P(\psi_1 + \psi_2)$$

for in Fig. 1 of the article the forces acting at any section should be resolved in two directions which are not orthogonal. One of these directions is along the neutral line and the other is parallel to the plane of the rotated cross-section—in fact, as F is shown in Fig. 1. The correct form of equation (14) is then

$$EI(1-\alpha)\frac{d^5y_1}{dx^5} + \left(P - \frac{kEI\lambda}{AG}\right)\frac{d^3y_1}{dx^3} + k\frac{dy_1}{dx} = \frac{d}{dx}p(x).$$

However, if y is the total deflection (equal to $y_1 + y_2$) the following fourth-order equation is obtained:—

$$EI(1-\alpha)\frac{d^4y}{dx_4} + \left(P - \frac{kEI\lambda}{AG}\right)\frac{d^2y}{dx^2} + ky = p(x) - \frac{EI\lambda}{AG}\frac{d^2}{dx^2}p(x).$$

The boundary conditions for a number of important cases are as follows.

(*a*) *At a pinned end*:—

$$y = 0;\ M = 0 \text{ or } \frac{d^2y}{dx^2} = -\frac{\lambda p(x)}{AG(1-\alpha)}.$$

(*b*) *At a built-in end*:—

$$y = 0;$$

$$\frac{dy}{dx}\left(1 - \frac{\lambda^2 EIk}{(AG)^2}\right) + \frac{d^3y}{dx^3}\frac{\lambda EI}{AG}(1-\alpha) = -\frac{\lambda^2 EI}{(AG)^2}\frac{d}{dx}p(x).$$

(*c*) *At an end with specified* M *and* V:—

$$EI(1-\alpha)\frac{d^2y}{dx^2} - \frac{kEI\lambda}{AG}y = -M - \frac{EI\lambda}{AG}p(x)$$

and,

$$EI(1-\alpha)\frac{d^3y}{dx^3} + \left(P - \frac{kEI\lambda}{AG}\right)\frac{dy}{dx} = -\frac{EI\lambda}{AG}\frac{d}{dx}p(x) - V.$$

Yours faithfully,
P. C. DUNNE.

Farnborough,
Hampshire.
October 22, 1956.

Weekly Survey

Cover Picture: *A stage in the manufacture of radio receiving valves is illustrated in this week's cover picture. The valves are loaded into a rack and voltage applied to their heaters with the object of raising the cathode to temperatures suitable for creating good electron emission.*

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Help for the Railways

The strategy behind the plan for British Railways which was set out in a White Paper last week by the Minister of Transport is commendable enough. The British Transport Commission is to receive loans from the Government up to a limit of £250 million to cover annual deficits up to the early 1960's. The modernisation plan is to be speeded up and it is expected that by the 1960's the benefits of this plan will be felt in operating costs and conditions. The loans will be repayable by instalments after a specified period and they are liable to interest. There is thus a clear connection in the plan between the provision of loans and capital investment under the modernisation scheme. The railways are to be made as efficient as possible as quickly as possible so that they can achieve a break-even point with the minimum delay. The British Transport Commission are satisfied, and there will be few who will challenge the claim, that the railways cannot raise more revenue by further increasing their fares and charges and that this problem has been made worse by the deliberately complicated system of adjustment of railway tariffs. It can also be argued with reason that the deliberate policy of giving the railways a low priority in capital investment following the depression of the 1930's, when the railway companies were starved of capital, has made the problem of modernisation very much a legacy from the past which might be written off as a capital charge on the present and the future.

There is, however, also a direct connection between the new financial scheme and the size of the railway operating deficits over the next few years. It will be fatally easy for those whose interest in the railways is non-technical to look upon these loans as a means of subsidising the current operations of the railway system. It is perhaps unfortunate that the White Paper has been published at the same time as the N.U.R. has made a concrete demand for higher wages for its members. It will take a very firm adherence to the objective under the new plan to ensure that the proposed loans are not used as excuses or bargaining points to establish the principle of a never-ending subsidy for British Railways.

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Waiting Time for Locomotives

The locomotive industry continues to work its way through that special brand of purgatory which is reserved for those who supply nationalised industries. Judged by the production figures for the first half of 1956, the industry as a whole has fared reasonably well. Output of Diesel locomotives between January and June was 501, compared with 333 in the same period of 1955. Both home and export deliveries were good, the export market taking 289 locomotives and the home market 212. Activity in the industry is reported to be currently at a high level but there is every likelihood that export work will ease off, for the recent high level of production has not been supported by a sustained export order book. Both Argentina and India have called for tenders, the first for 200 Diesels and the second for 100 Diesel-electric locomotives, and it remains to be seen how far those British concerns which have tendered are successful.

These expectations would be rather thin gruel were it not for the orders on hand from the British Transport Commission. Over the locomotive industry hangs the tantalising prospect that British Railways expect to have 2,500 main-line Diesels, to say nothing of other power units, delivered over the course of the modernisation programme at a cost of about £125 million. The pilot orders put out last year are now a significant proportion of the current throughput of the big locomotive makers. When these are delivered—the bulk of them are expected in the second half of 1957—tests will be made by B.T.C. and presumably a final decision reached about the role of the Commission's own workshops in the locomotive modernisation scheme. On the ability of the private industry to win a substantial part of this modernisation programme hangs its hope of prosperity in the next decade. Despite the pre-occupation of the B.T.C. to maintain an attitude of non-commitment and objectivity in this long period of gestation until pilot locomotives are tested, it will be surprising if private industry does not benefit substantially from the scheme. Having encouraged the gestation, it will be difficult for the Commission to abandon the children and the parents. The awkward question for all concerned is, of course, which family is going to thrive most in the end.

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Testing Missiles in Flight

Last week, for the first time since the Royal Aircraft Establishment took over the weapons-firing range at Aberporth in South Wales some eight or nine years ago, Press representatives were admitted to see something of the work that goes on there. R.A.E. Aberporth provides experimental missile flight-testing facilities both for its parent department, R.A.E. Farnborough, and for the guided-weapons manufacturers to carry out full-scale testing of prototype air-to-air and surface-to-air missiles and components such as propulsion motors, guidance systems and control systems mounted on test vehicles. It is also the centre for developing flight instrumentation systems for weapons.

In the case of air-to-air test vehicles or missiles, preparations are completed at the manufacturers' works and they are flown in according to the schedule laid down by the Aberporth controller, direct for their test. Surface-to-air vehicles, on the other hand, are made ready and tested at Aberporth by representatives from the manufacturers. After their boost motors have been assembled and checked, they pass to the launching area itself—now in process of considerable extension. Located on the area there is a variety of launchers, some with travelling carriages, while others—now tending to gain favour—are of the "zero travel" type.

For testing missiles under development for the Royal Navy, a three-barrel launcher, controllable in elevation and bearing, and a gyro-stabilised tracking radar are mounted on a Clausen rolling platform, as shown in the accompanying illustration—a freely-floating simulated "ship" which can be induced to pitch and roll at variable rates by hydraulically actuated "urgers." Control of firing and radar is carried out below deck. Pilotless target aircraft, sometimes used to test weapons, are flown in from Llanbedr airfield.

The programming and sequencing of the firing operations are remotely controlled by a controller in a central control room, but before the firing sequence can be initiated a safety key has to be inserted in the master circuit by the range officer, who works in a safety control post overlooking the launching area itself. He also controls a safety key for the "Command Break-up" system to ensure that the latter shall not be inadvertantly operated before the missile is fired. "Command Break-up" provides for disintegrating the missile should it stray from its proper course.

The firing range extends across Cardigan Bay, and around the coast are observation posts from which the test vehicles are tracked by kine theodolite, high-speed cameras, radar and doppler system transmitters—all automatically operated, and synchronised from a central timing unit in the instrumentation building at Aberporth. In the latter also are the doppler receivers, and the telemetry receivers receiving the incoming signals transmitted by the test vehicle. Two main types of receiver are employed—a 24 channel time-multiplex system which automatically produces 23 separate photographic traces, and a pulse-position system for high-frequency recording.

The data-recording section, where all the records of telemetered and ground-observed information are analysed, is becoming increasingly mechanised. In the case of optical records produced by the ciné theodolites and cameras, the human interpreter cannot be entirely eliminated, but his work can be greatly reduced by means of a coded-disc semi-automatic reader now under development.

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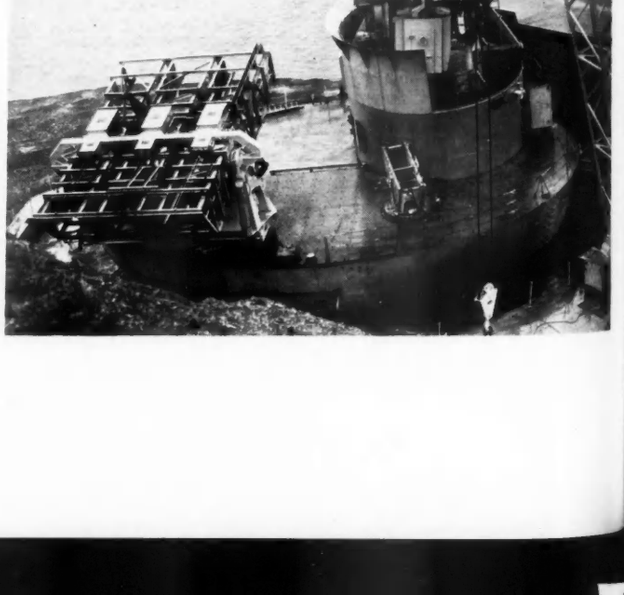
New Jets for B.O.A.C.

As expected, the Government have authorised British Overseas Airways Corporation to purchase 15 Boeing 707 air-liners to be powered by Rolls-Royce Conway bypass turbojets. The aircraft on order—shown in the drawing—are known as the 707-420 version and will be 153 ft. long with a wing span of 143 ft.; the



For testing naval missiles the Clausen floating platform can be induced to pitch and roll.

maximum all-up weight is 295,000 lb., with a maximum landing weight of 195,000 lb. The aircraft will carry from 107 to 170 passengers, according to layout, and cruising speed will range from 525 to 575 m.p.h. The maximum cruising height will be 40,000 ft., and the maximum still air range between 6,500 and 6,750 statute miles.

Most people will agree with B.O.A.C.'s chairman, Mr. Gerard d'Erlanger, " that the acquisition by B.O.A.C. of large, high-speed and long-range turbojet air-liners is imperative if the Corporation is to secure its competitive position on world routes, especially across the North Atlantic, from 1960 onwards." What is surprising is that B.O.A.C. were so slow in becoming conscious that this need would arise. It is less than a year ago that they expressed a complete lack of interest in the civil version of the Vickers 1000 long-range transport, on the grounds that the Comet 4 and the Britannia would fulfil their needs for the immediate future.

The B.O.A.C. Boeing 707 fleet will operate on routes across the North Atlantic, the United States and the Pacific to Australia, from airports of the highest standard. To supplement them, B.O.A.C. are now discussing with the de Havilland Aircraft Company a specification for a new aircraft, known as the D.H. 118, with speed and range comparable with the large American jet transports, but somewhat smaller and capable of operating from a wider range of main-line airports, suitable for the many trunk routes on which traffic density is unlikely to warrant the use of the larger aircraft, as well as on the North Atlantic. This aircraft is intended to come into service in 1962. The time factor is important: by 1962, no doubt, Boeing and Douglas will have produced comparable developments, and by that time most of the major operators will already have in service either the D.C.8 or the Boeing 707 on their longer routes. They will tend, for convenience in maintenance, to favour aircraft with the same family background.

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Amber from Machine Tools

There is a slight touch of autumn in the latest figures released from the machine tool industry. Despite the July exhibition at Olympia the rise in the accumulation of orders was checked in that month, when the order book stood at £104·6 million compared with £105 million at the end of June.

The main cause of the slight dip in the value of orders on hand was improved delivery, which reached the peak level of £7·7 million in July. There were substantial orders booked in July and it may be that something of an artificial boost was given to these by the July exhibition, for the orders booked in June were much lower and, taking June and July together, orders at £10·3 million were over £2 million less than the same period of 1955. In the export market both export orders and deliveries were high but there has been a slight decline in export deliveries over August and September.

The trend of activity in this industry is always taken as a rough and ready guide to the health of the capital goods industries. Those who are bold enough to try to forecast economic trends expect only a minor setback in the demand for plant and machinery over the next 12 months. The latest official view of industrial investment by industry expects a fairly sharp decline in new factory building and a small increase in investment in plant and machinery. It would be expected that the higher rate of factory building in 1956 would sustain a substantial demand for new equipment in 1957, and it would not be until the later part of next year that a drop in new factory construction would work itself out in a corresponding drop in the demand for new machinery. There is, indeed, a general consensus of opinion that machinery manufacturers, including machine tool makers, can expect good business for some time to come. There may be a

Boeing 707 for B.O.A.C.

modest decline in new orders accompanied by a continuing improvement in the rate of delivery as the credit squeeze forces labour out of less essential industries. These forecasts of the less or more are, however, subject to such margins of error that the prospect for the next 12 months is exceedingly difficult to assess with any confidence. On the whole, any slackening in the impetus of capital investment should flash no more than an amber light at the engineering industry.

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Diesels, Vehicles and Ships

The results of two Diesel engine manufacturers published last week suggest that profit margins in that industry will continue to fall, though orders are good and turnover tending to increase. Crossley Brothers' chairman, Sir Kenneth Irwin Crossley, dwells at some length in his company's report on the problem of rising costs. He points out that, since 1950, wage awards in the engineering industry have amounted to a 53 per cent. increase, whereas the average increase in the company's prices has been only 37 per cent., " which figure is substantially greater than that of our chief overseas competitors in Germany, the United States and elsewhere." Despite this disadvantage the order book stands at over 12 months' work, including a very satisfactory proportion of exports. But Sir Kenneth is not optimistic on his company's ability to maintain profitability at the present level. Peter Brotherhood also report a moderate decline, as forecast a year ago by their chairman, Mr. A. M. Neal, as a consequence of the larger proportion of work being undertaken for the Services at narrower profit margins, and generally keener competition.

Armstrong Shock Absorbers Limited, the largest suppliers of shock absorbers to the motor industry, have suffered a considerable decline in profits, from £180,000 in the year ended June 30, 1955, to £82,000 this year. Their chairman, Mr. William Armstrong, talked of the considerable recession which followed last Christmas as a result of a fall in exports and the Government anti-inflationary measures at home. He drew comfort from the " great strides " made by the company's Heli-Coil division, whose products find a wide market outside the motor industry. But H. A. Saunders, the Finchley firm of car distributors (Austin main agents), increased their earnings; " we had eight excellent months and four indifferent ones," suggesting that all buying has not been squeezed out of London yet. The mention that exports of industrial tractors to Europe (the new Bristol 25) went very well, particularly to Germany, is interesting, though " business has fallen off badly in the last two or three months."

The two comments on shipbuilding came one from a most highly rated shipbuilder, R. and W. Hawthorn, Leslie and Company, Limited, and the other from Lyle Shipping Company, Limited. The former raise their dividend by 3 per cent. to a total of 20 per cent. and report a very good year. Sir Robin Rowell, the chairman, said that given reasonable stability in the national economy " we can look forward to satisfactory trading over the next few years." Profits rose by £85,000 to £508,000. They have a heavy modernisation and expansion programme in hand. Colonel Peter Macfarlane, chairman of Lyle Shipping, repeated the now almost standard remarks of all shipowners about shipbuilders, that costs are ever-increasing, and are generally higher than estimated. He suggests a new ship subsidy—it would be " helpful and sensible " if the Chancellor were to put even a proportion of taxation paid by shipowners into a " kitty " for new ships. Why not indeed, and why for ships only and not excavators, rolling mills or computers? Lyle Shipping's profits rose by £295,000 to £1·1 million.

Other remarks of interest were made by the chairman of Wellington Tube Works, Limited, Mr. Douglas W. Turner, who said that his company's sales of heat-transfer equipment—" which until a few years ago was virtually an American monopoly "—had continued to expand. Aluminium Limited earned in the first three-quarters of this year nearly as much as during the whole of 1955, but their president, Mr. N. V. Davis, warned that " the gap between supply and demand which existed until a few months ago has been substantially reduced if not eliminated " as a result of increased production. In fact there is no longer any shortage of aluminium, nor any surplus either.

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The Dowty Group

Increasingly since the war success has belonged to those manufacturers who have been bold and imaginative enough to strike into new fields and able to see, for their experience and skills, increasing applications and opportunities throughout industry. The development of the hydraulic lift for tractors brought fame and success to Mr. Harry Ferguson. The development of aircraft hydraulic systems and undercarriages has done the same for Sir George Dowty. The difference is that Ferguson stuck to agriculture whereas Dowty spread from aircraft to applications in the mines, transport and many other industries, including agriculture. The Dowty Group has expanded in 25 years from nothing but the designing skill of a young draughtsman in 1931, now their chairman, to a multi-factory group with fixed assets of nearly £2 million. Over one million aircraft undercarriages and hydraulic units provided the background for expansion into the new fields. The first hydraulic pit prop was made in 1946, since when a large mining engineering business has been built up. Licences for the system have been acquired by French and German firms. A large new factory is to be opened this year for the manufacture of hydraulic units for a wide range of applications. Gas-turbine fuel systems, hydraulic railway buffers, automatic hydraulic transmission systems, the " Roofmaster " automatic system of coal-face roof support and conveyor movement are some of the Group's newest products. A large research and design team is engaged on development projects in the fields of nuclear engineering, electronics and automation.

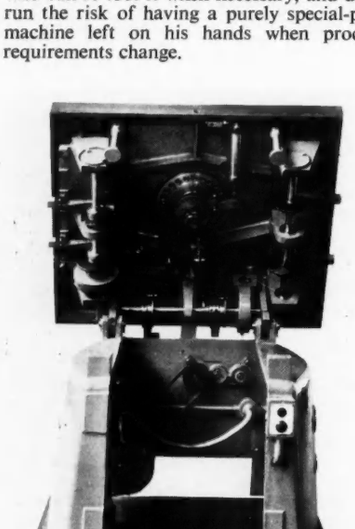
Despite all these new departures, the Group's profit for the year ended March, 1956, was nearly £1½ million before tax, slightly above the previous year's. Commenting on an expected decline in orders for military aircraft, Sir George Dowty told shareholders that " the other fields into which we have entered can do more than redress any reduction which we are likely to sustain through a curtailment of aviation business." With subsidiaries in Canada, Australia and the United States the Dowty Group are well established overseas. Their rapid growth since the war is a good example of the strength which is to be found in a well diversified range of products embodying the same basic principles and utilising available skills to the full.

"COMPASS AUTOMATION BASE"

AUTOMATIC CONTROL OF PRODUCTION OPERATIONS

Special-purpose machines, designed to carry out a series of operations automatically, are of ever increasing importance in engineering. They may be for machining, shaping or otherwise working on components, for assembling finished components, or for some combination of both these operations, many different means being employed to achieve these ends. There are, however, two features which unite on common ground many machines which are otherwise quite different; they have several fixed work-stations, with mechanisms for carrying out the desired operations there at the appropriate time, and they have means for transporting the component to each station in turn. It follows that a relatively simple indexing device, coupled with a number of automatic work-stations, can be used as the basis for an extremely large range of automatic and semi-automatic machines.

Such a device, while possessing the basic features mentioned, should also be capable of modification within wide limits. It will then relieve the machine designer of the responsibility for considering basic principles, and leave him to concentrate on tooling. Because it is adaptable, it will also be of advantage to the user, who can re-tool it when necessary, and does not run the risk of having a purely special-purpose machine left on his hands when production requirements change.

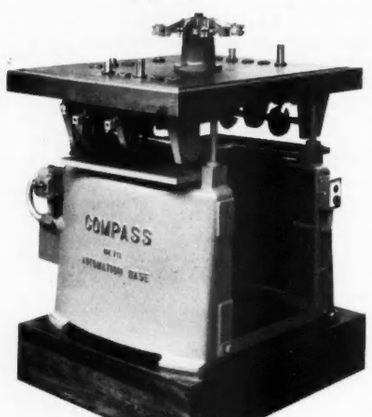


The work-table can be lifted on its hinges to give access to the mechanism. The plate-type cams are visible in this illustration, together with the indexing dial plate and ratchets.

The "Compass Mark VII Automation Base," introduced by Bristol Repetition, Limited, Feeder-road, Bris ol, 2, has been designed to act as the foundation on which many different types of automatic and semi-automatic machines can be built, and provides a range of indexing and work-station arrangements which can be varied according to requirements. The design has been developed from a series of machines built for use in the manufacturers' own works, and is fully established in principle and practice. The basic movements provided can be adapted for most types of machining, including such operations as drilling, tapping, milling, reaming, slotting, countersinking and parting-off; forming operations such as pressing, piercing, bending, flanging and flattening; miscellaneous operations such as riveting, marking, polishing, checking and counting; and assembly of components either made in the machine or fed to it at one or more points.

WORK-HEADS MOUNTED AS REQUIRED

The machine consists, basically, of a cast iron work table, 36 in. by 32 in., mounted 33 in. from ground level on a cast iron frame. In the centre of the table is a 2 in. diameter indexing spindle, carried on a roller bearing at the upper end and a sealed ball bearing at the lower end. A suitable head or carrier for the work-pieces can be attached to this spindle. The surface and all



The "Compass automation base" has a variable indexing mechanism and up to 14 work-head actuating push-rods. It can be used as the foundation for a great variety of automatic and semi-automatic machines.

four edges of the work table are machined for the attachment of work-heads, which can be located as required; they are operated by push-rods extending through the table surface. With suitable work carriers and work-heads the machine can operate fully automatically with hopper feed, and two or more machines can, if necessary, be built into one unit to perform any required number of operations. Alternatively, the machine can be used semi-automatically with manual loading and unloading, the operator being either seated or standing, whichever is more convenient.

The work-head spindle is indexed by a pawl and ratchet wheel mechanism operated by a cam. A check pawl and ratchet wheel prevent over-run, and there is a pneumatic dashpot to absorb the inertia of the moving head. A dial plate positions and locks the work-head at each station by means of a hardened and ground steel pin and a nitrided steel bush, all the bushes being standard drill-jig bushes, which facilitates replacement. The indexing mechanism gives a choice of 6, 8, 12 or 24 stations at will, and any number of stations is obtainable simply by changing the ratchet wheels and dial plate. Indexing time can be chosen to suit the speed of the work cycle, the standard range of 12 indexing cams giving fast, medium or slow indexing for the four station ranges mentioned. Fast, positive indexing, in as little as one-eighteenth of the cycle time, is possible.

The design of the machine allows for any number of work-heads up to 14, disposed as required round the central spindle, the usual arrangement being to have them more or less equally spaced on three sides of the table, leaving the front end open for loading and unloading. Reciprocating motion of up to 2 in. in a vertical direction is provided for each of the work-heads, this motion being obtained from cams mounted on camshafts beneath the table. It follows that by the use of suitable levers or other mechanisms the work-heads can be moved in any direction, and by using cams with appropriate contours any required combinations of advance, feed and return are possible on any of the heads.

There are three camshafts running in sealed ball bearings, and connected by bevel gears to extend round three sides of the machine. The drive is from a 1 h.p. motor mounted in the base; this motor also drives the indexing mechanism, so ensuring synchronisation of all movements. An easily-accessible pick-off gearbox in the camshaft drive enables the machine cycle time to be varied between ¼ second (240 cycles per minute), and 10 seconds (6 cycles per minute). Other cycle times could be arranged by suitable modifications to the motor or gearing.

The cams are of the simple, plate type used on automatic lathes, and each one can be fitted, removed and adjusted angularly without removing the camshaft or interfering with the setting of the other cams. Above each cam is a guide bush (like the indexing mechanism bushes these guides are standard drill-jig bushes), and a hardened and ground steel push-rod, which transmits the cam motion through the table to the point where it is picked up and connected to the work-head. Any push-rod which is not required for a particular set-up can be removed, together with its upper bushing, and the resulting cavity filled with a loose, drop-in plug, leaving a flush surface at that point.

A self-contained, electrically-driven pump and tank provides coolant for any machining operation set up on the machine, the motor being controlled, like that which powers the machine, through push-buttons. A suitable channel is provided round the edge of the work-table for collecting coolant, which is returned by flexible hose to the tank.

The work-table is hinged at the rear, and can be lifted up to give access to the mechanism underneath. This construction also makes it possible to remove the table complete with work-head, tools, cams and indexing mechanism and substitute another, ready set up, when production changes are required. At present it is only intended to supply the base, leaving the user to design and fit the work-heads and tooling, but the manufacturers are prepared to make recommendations on the tooling layout, and also to suggest the names of suitable suppliers, some of whom are ready to undertake the complete adaptation of the base for a particular job. The question of supplying standard heads for such operations as drilling, milling and other types of machining is under consideration, and the manufacturers are prepared to make larger models if necessary.

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TRANSMISSION BELTING

In spite of its indifferent pulley grip, necessitating a high working tension, frictioned rubber and canvas belting has long been regarded as the most popular general-purpose transmission belt used in industry. It is claimed, however, that a recently-developed belting of this type, known as Maxigrip, has succeeded in overcoming this difficulty, by incorporating a specially constructed driving ply which maintains a tenacious grip on the pulley throughout its life, while, at the same time, taking a full share of the tension.

This driving ply is woven from patented yarn, in which the cotton and rubber latex are intermingled under vacuum and spun together; the process causing each fibre to be coated with rubber before being twisted and woven.

Maxigrip, which is manufactured and marketed by George Angus and Company, Limited, Angus House, Newcastle-upon-Tyne 1, is claimed to be suitable for all drives now fitted with rubber and canvas belting or balata belting.

A NEW BEARING ALLOY WITHOUT TIN

"ALZEN 305 WHITE BRONZE"

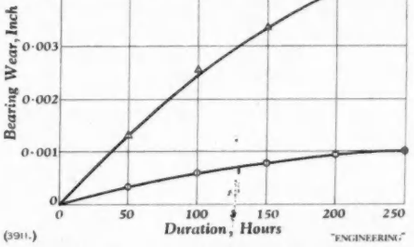
As a result of war-time shortages in central Europe, a search made to replace bearing materials containing copper and tin culminated in the adoption of new alloys having zinc and aluminium as their main constituents. After the termination of hostilities however, the engineering industry reverted gradually to the traditional bearing alloys. This return was dictated not so much by a conservative outlook but rather by the fact that insufficient time had been allowed for the complete development of the new alloys. Difficulties in manufacture had not been entirely solved and failures had taken place owing to incorrect applications. Some years after the war, when the prices of copper and tin rose steeply, compared with the relative stability of the rates for aluminium and zinc, a demand arose for the resumption of the work on the war-time alloys.

After some four years of research and application tests on a commercial scale, the Vereinigte Oesterreichische Eisen- und Stahlwerke, A.G., (Vöest), Linz-Donau, Austria, placed on the market a zinc-aluminium-copper alloy, to which they gave the name Alzen 305. This contains 30 per cent. of aluminium, 5 per cent. of copper, the balance being zinc, a composition which has eliminated most of the problems encountered in the foundry and, incidentally, is capable of being gravity or pressure die-cast, with a consequent saving in machining time and the achievement of close dimensional tolerances. The alloy exhibits a structure similar in form to the tin bronzes, namely, a finely distributed hard ternary eutectic of copper-aluminium-zinc in a relatively soft matrix of zinc-aluminium. The mechanical properties of Alzen 305 compare favourably with those of various bronzes and gunmetals as may be seen in Table I.

TABLE I.—DATA ON CHILL-CAST NON-FERROUS METAL BEARING ALLOYS.

Alloy	Specific gravity	Yield stress (Approximate values)	Ultimate tensile stress	Elongation on $4\sqrt{A}$	Brinell hardness
		Tons per sq. in.	Tons per sq. in.	Per cent.	Numbers
Alzen 305	4·8	15	20‡	2‡	100–150
Gunmetal LG2-C*	8·7–8·9	8	12‡	Nil	55–65
Phosphor bronze PB2-C*	8·7	11	17‡	3‡	90‡
Leaded phosphor bronze LPB1-C* ..	8·7	9	14‡	1·5‡	65–75
Phosphor bronze 2B8†	8·7	10	16‡	1·5‡	60–80

* B.S. 1400 : LG2-C are 85/5/5/5 leaded-gunmetal castings; PB2-C contain 11-13 per cent. tin and not less than 0·15 per cent. phosphorus; and LPB1-C contain 6·5-8·5 per cent. tin, not less than 0·30 per cent. phosphorus and from 2·0 to 5·0 per cent. lead.
† British Standard Specification for Aircraft Materials and Components; 2B8 contains minima of 10 per cent. of tin and 0·50 per cent. of phosphorus and also 0·25 per cent. of lead.
‡ Minimum values.



Comparative wear tests on Alzen 305 zinc-aluminium-copper alloy and 2B8 phosphor bronze bearings, both chill-cast. The running speed ranged from 1,300 to 1,600 ft. per minute and the load from 130 to 200 lb. per sq. in. of projected area. The lubrication was by drip feed and the maximum recorded temperature, 220 deg. F.

The new alloy is covered by a British Patent and in pursuance of agreements recently signed in London and Vienna between British engineering interests and Vöest, Alzen Limited, London, are the sole licensees for the alloy in the United Kingdom, the British Commonwealth, the United States, Spain, Japan and other territories not covered by the originators of the material. Furthermore, C. and L. Hill, Limited, Stringes-lane, Willenhall, Staffordshire, the non-ferrous metal founders of the Owen Organisation, have been granted an exclusive licence to manufacture and sell the alloy, in ingot form, in the United Kingdom, and a non-exclusive licence for castings and fabricated parts.

In conclusion, some results obtained in an investigation on the bearing properties of the new alloy, conducted in the research and development department of Rubery, Owen and Company, Limited, will be of interest. The tests were carried out in a special machine designed to test two bearings simultaneously under similar conditions of load and speed. The bearings consisted of Alzen 305 and phosphor bronze 2B8, both in the chill-cast condition. The Brinell hardness of the journal was 350, the diameters of the two bearings were 1·56 in. and their length 1·25 in. The running speed was 1,315-1,600 ft. per minute, the load 130-200 lb. per sq. in. of projected area, and the bearing clearance, 0·003 in. per inch diameter. The drip-feed method of lubrication was adopted and the maximum recorded temperature was 220 deg. F. The results shown in graphical form below, indicate that bearings of the new alloy may be expected to have a substantially longer life than the phosphor bronze under the particular conditions imposed.

It is further pointed out that in the event of lubrication failure, complete seizure will not occur with the new alloy until a bearing temperature approaching 400 deg. C. (750 deg. F.) is reached, and that even when seizure occurs the bearing does not weld to the shaft. Apparently, little or no shaft grooving results, and in most cases the bearing itself is not destroyed.

Another interesting point is that the new alloy has been successfully continuously-cast, giving an ultimate tensile stress of up to 36 tons per sq. in., and an elongation of up to 8 per cent.

The corrosion-resistance properties of the new material are described as being "midway between the bronzes and the zinc-base casting alloys." In consequence the use of Alzen 305 in sea-water corrosive conditions is not recommended.

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RECORDING FLAW PATTERNS ON METAL SURFACES

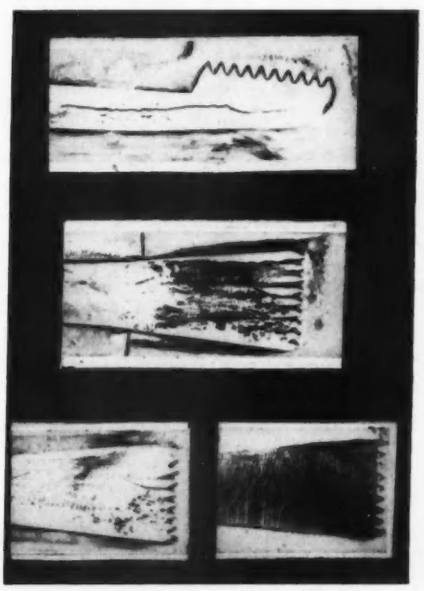
A simple, speedy and inexpensive method of recording the results of magnetic and other surface flaw-detection examinations of tools, components or welds has been developed by Industrial Tapes Limited, Speedfix House, 142-146 Old-street, London, E.C.1, working in close association with Radalloyd Limited, 3 Crescent King-street, Leicester.

The method is employed in conjunction with a normal flaw detector of the magnetic type. The component under examination is covered with one of the firm's Speedfix tapes specially developed for the process. This has a white surface which is coated with special flaw-detection "ink" during the inspection. The metal component is placed between the jaws of the flaw detector in the normal way and the magnetic flux reveals the presence of any flaws. The component is then covered with Speedfix Vinyl No. 12 transparent material which "fixes" the detection ink and provides a clear and permanent record of the flaw pattern, as may be seen in the illustration below. These records can be mounted and filed for future reference.

NON-MAGNETIC MATERIALS

Other tapes have been developed for the non-destructive surface-flaw examination of non-magnetic materials. Thus, for example, Speedfix Vinyl No. 15 (black hard mix) is used in conjunction with fluorescent penetrating media supplied by Solus-Schall Limited, 15 Clipstone-street, Great Portland-street, London, W.1. The surface to be inspected is first coated with the fluorescent substance and after allowing the requisite time for the product to penetrate, any excess is removed from the surface and a developing powder applied. The special tape is placed on the part to be inspected and a pressure-sensitive adhesive draws out the fluorescent penetrating medium on the flaw in the surface. The tape is then stuck on a piece of transparent plastics material and the flaw pattern is revealed when the pressure-sensitive side of the tape is placed under an ultra-violet lamp.

Where coloured penetrating media, (also supplied by Solus-Schall Limited, or colloidal graphites, furnished by Colloidal Graphite Limited, 6 St. Dunstan's-lane, London, E.C.3) are employed, Speedfix No. 15 (white hard mix) is recommended. The component to be inspected is treated with the penetrating medium or with the graphite and the tape placed over it. On removal, the penetrating medium is drawn out of any crack or flaw by the pressure-sensitive adhesive, and it can be seen clearly on the pressure-sensitive side of the tape. This method, it is pointed out, is of great value where hair-line cracks, barely visible to the naked eye, have to be detected.



Typical flaw patterns on metal surfaces fixed and recorded for future reference by means of Speedfix flaw-detection tapes developed for the purpose.

Book Reviews

VEHICLES ON THE ROAD

Traffic Engineering. By THEODORE M. MATSON, WILBUR S. SMITH and FREDERICK W. HURD. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (12.50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (94*s*.)

Traffic engineering is a branch of civil engineering which has expanded very rapidly in the last 30 years. It deals exclusively with road traffic, although from its name it might be expected to include railway and telephone traffic as well. In the United States of America the subject has been given much more attention than in this country or elsewhere in Europe, the Bureau of Highway Traffic of Yale University, for example, offering a full academic year's post-graduate course, and the three authors of *Traffic Engineering* are the late director, the present director and the associate director of the Bureau. In addition, the Institute of Transportation and Traffic Engineering at the University of California gives a year's graduate course, and several other universities include the subject in their curricula. Similar training, however, is now available at some places on the European continent and in this country, including University College London, and King's College, University of Durham.

The book is based on the teaching given at Yale, and is divided into the following sections: characteristics (of road users, vehicles, traffic and accidents); regulations; control devices and aids (signs, signals and road lighting); design; administration and planning. The first section gives some useful data on driver characteristics, and points out that reaction times vary considerably, according to the conditions. Average brake-reaction times, for instance, range from 0·24 sec. in ideal conditions to 1·65 sec. under normal driving conditions if the car ahead has no brake light. Stopping distances are dealt with rather summarily in this book; the recommendations of the American Association of State Highway Officials are quoted, but there is no information on the braking distances of actual vehicles. Measurements made in this country by the Road Research Laboratory in recent years have shown that the average stopping distance from 30 m.p.h. varies from 50 to 200 ft. This variability is a very important factor. A car with poor brakes may be following one with good brakes and the gap of 40 to 50 ft. between cars travelling at 30 m.p.h., which is very common, could obviously be dangerously small.

A matter of great importance to highway engineers is the question of the capacity of road systems and the *Highway Capacity Manual* has become the standard work on this subject in many countries. It gives definitions of three kinds of traffic capacity, which can be summarised briefly as follows:—

Basic capacity = Maximum flow under ideal road and traffic conditions (all cars speeds being uniform);

Possible capacity = Maximum achievable flow under existing road conditions and with existing traffic;

Practical capacity = Maximum flow which gives reasonable driving under existing road conditions and with existing traffic;

Of these, the first is somewhat artificial and does not seem to merit a special term. The other two are both useful, and have become widely accepted. Matson, Smith and Hurd confuse the issue by introducing four new terms, which are not clearly defined—the combinations of "theoretical" or "practical" or "maximum" or "design" capacity. Apparently "theoretical maximum capacity," "practical maximum capacity" and "practical design capacity" correspond roughly to the three *Highway Capacity Manual* terms. There seems, however, to be no good reason for replacing the older terms and every reason for retaining the last two.

Neither the *Manual* nor the present book explain very clearly how the practical capacity is determined. What may or may not form reasonable driving conditions is a subjective matter, and difficult to assess. It was suggested in 1948 by Schuhl* that one very important criterion is an economic one. Increasing congestion on roads causes reduced speeds, and hence, losses of time and frequently extra operating costs, and these increase more than in proportion to the volume of traffic. If such losses can be evaluated in money terms, they can be used in conjunction with the cost of road improvement to answer the question: "Has congestion on this road reached the point where we can save money by improving it?" If the answer is "Yes," the traffic on the road may be said to have exceeded its "economic capacity."

The authors devote one chapter to the important subject of traffic signals, but their approach is very disappointing. They recognise that, subject to safety considerations, signals should be adjusted to give the minimum average delay to vehicles. They give a rather elaborate formula for delay at fixed-time signals, assuming a uniform rate of arrival, and based on Greenshields' observations at a single intersection. Curves derived from this formula are given, although the authors admit that, in practice, vehicle-arrival times approximate to a random series and this can affect delays to a very great extent. They give an *ad hoc* method of allowing for the randomness of traffic, based on the arbitrary criterion that the number of arrivals shall not exceed the maximum which can be discharged in more than 5 per cent. of signal cycles.

The Road Research Laboratory has done a great deal of work on delay at traffic signals both of the fixed-time and vehicle-actuated types, assuming random arrivals and using an electronic computer (the Pilot Model ACE at the National Physical Laboratory). A formula for delay at fixed-time signals covering all conditions likely to be met has been found, and methods of setting signals to minimise delay have been given.* These results show that the criterion given by Matson, Smith and Hurd is not, in general, the right one, and would give unnecessarily long cycle times and extra delay. At a typical intersection, the minimum delay occurs when the cycle time is such that about 30 per cent. of cycles are over-loaded instead of 5 per cent.

This emphasises the importance of comprehensive research on traffic signals. Despite the very large number of signals in the United States, research on the subject has been very incomplete there, and there is no reference in this book to any work outside the United States. This is also true of the other subjects covered, with the exception of the British work on transition curves by Royal-Dawson, Leeming and others.

The section on regulations contains some useful information, although much of it refers to special conditions obtaining in the United States. The section on design is very thorough and, in particular, shows a number of intersection layouts, including elaborate examples of the use of channelisation and of acceleration and deceleration lanes both for right and left-turning traffic. The Americans are much more inclined towards designs of this type than the British, but, unfortunately, no evidence of their value in reducing accidents is given. However, common sense suggests that methods which reduce the number of factors which a driver must simultaneously take into account as he enters a road are likely to be beneficial.

Taken as a whole, the book gives a useful summary of American thought, and it is the first complete text-book on traffic engineering. It is to be hoped, however, that a similar book based on experience and research done in this country will be available in the near future.

* Schuhl, A., "Design Width in Relation to Traffic," *La Route*, No. 166 (bis), pages 33-37 (1948).

* Road Research Board, *Road Research* 1954, pages 26-27. (H.M. Stationery Office, London, 1955.)

ROLLING STOCK ON RAILS

British Railways in Action. By O. S. NOCK. *Thomas Nelson and Sons, Limited, Parkside Works, Edinburgh, 9.* (25*s*.)

The author of this well produced volume is not only a highly qualified engineer, deeply interested in railway construction and operation for their own sake, but is professionally engaged in designing signalling and brake equipment, in the use of which he has had considerable practical experience. He has also spent much time travelling on locomotive footplates in widely varying conditions and in observing railway working at first hand in many other ways. The knowledge thus acquired has found expression in several earlier works and in papers read before technical institutions, but in this one he has sought more particularly to convey something of the work of the men on whom fall the day-to-day tasks of regulating and handling the ever varying traffic on British Railways.

Emphasis is laid chiefly on locomotive running, with the aid of reports of runs made, usually on the engine, by the author or other competent observer, including electric, Diesel and gas-turbine traction. Cross-country routes find adequate notice, as well as the main lines, but the operation of signal boxes, control offices, stations, rolling stock and motive power depôts, and other essential elements in the scene, including locomotive testing plants and test trains, are also treated, forming a concise overall picture of how the railways function. With much detail, attractively and clearly presented, the author shows what a remarkable volume of traffic is handled, often with facilities much less complete and adequate than is desirable—the result, in many cases, of the effects of two wars, the first of which had a particularly retarding influence on railway progress, which is felt even to-day.

To present so large a picture in reasonable compass has, of necessity, involved careful selection of material, effected with skill and discretion so that all classes of traffic—mineral, ordinary freight, passenger, and some special forms of each—are informatively discussed, to the accompaniment of an excellent series of photographs covering the widely separated locations and varying types of train concerned. The work is not, and was not intended to be, a technical treatise, although based throughout on accurate engineering knowledge, but it is a book to be read with advantage by any person desirous of understanding something of what goes on behind the scenes on the railways. It will bring pleasure to those who, whether in or out of the railway service, believe in the possibility of a prosperous future for railed transport and desire to see it assume and retain its place, under the enlightened application of modern methods of working and scientific ideas, among other and often competing forms of transport, the development of which has been due in some measure to its own initial success.

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A residential course on "The Treatment of Trade Wastes and the Prevention of River Pollution" is to be held at the Department of Civil Engineering, King's College, Newcastle-upon-Tyne, from April 1 to 12, 1957, inclusive. The course is open to all interested persons and is intended to meet the needs of those who have to deal with the disposal of liquid effluents, whether engaged in industry or as officers of local authorities or river boards.

END REACTIONS AND STRESSES IN PIPE-LINES

SPECIMEN CALCULATIONS FOR TWO AND THREE DIMENSIONAL LAYOUTS

By L. F. Randolph, B.SC., A.M.I.MECH.E.*

Concluded from page 496

The solutions of the three examples of pipe layouts presented below should indicate the simplicity of the method developed in the previous part of this article, pages 492-496, October 19. The errors made as a result of the simplifications employed will also be evident by comparison with the quoted answers obtained by the more refined grapho-analytical method. For nomenclature, see page 492.

EXAMPLE 1

The first example is that of a three-dimensional pipe layout, the details of which are shown in Fig. 3. The pipe details are as follow:—

Material, carbon steel

O/D = 12·5 in. $t = \frac{3}{8}$ in. R = 72 in. = 6 ft.

$I = 262{\cdot}8$ in.^{4} $\lambda = \frac{\frac{3}{8} \times 72}{6{\cdot}062^2} = 0{\cdot}735$.

Therefore β, the longitudinal bending stress factor = 1 (see Fig. 6).

E = 26·65 × 10^6 lb. per sq. in. (at 320 deg. C.) and T = 300 deg. C.

Determination of Centre of Gravity :-

Total length = 25 R ½-length = 12·5 R

L.H. part, A-S:

$$x' = \frac{(10 \times 5)\,R}{12{\cdot}5} = 4\,R \text{ (from C)}$$

$$z' = \frac{(2{\cdot}5 \times 1{\cdot}25)\,R}{12{\cdot}5} = 0{\cdot}25\,R$$

$$y' = 0$$

R.H. part, B-S:

$x' = 10$ R (from A)

$$z' = \frac{5\,(1{\cdot}77 + 10)\,R + 7{\cdot}5\,(3{\cdot}75 + 2{\cdot}5)\,R}{12{\cdot}5}$$

$$= \frac{(59 + 47)\,R}{12{\cdot}5}$$

$$= 8{\cdot}5\,R$$

$$y' = \frac{5 \times \frac{3{\cdot}54\,R}{2}}{12{\cdot}5} = 0{\cdot}7\,R \text{ (angle C D B = 135 deg.)}$$

Second Moment.—The necessary calculations are made in the accompanying Table I.

From Fig. 7, page 557, the thermal expansion is found to be 4·7 in. per 100 ft.

From equation (22), page 493, the deflection is

$$\Delta'' = L_a \times \frac{4{\cdot}7}{100} = \frac{17{\cdot}2 \times 72 \text{ in.}}{12 \text{ in./ft.}} \times \frac{4{\cdot}7 \text{ in.}}{100 \text{ ft.}}$$

$$= 4{\cdot}84 \text{ in.}$$

From equation (23)

$$F = \frac{\Delta'' \times \cos\theta_p \times \cos\theta_e \times E\,I}{M \times 1728}$$

where M is in ft.^{3}

$$F = \frac{4{\cdot}84 \times 0{\cdot}997 \times 0{\cdot}995 \times 26{\cdot}65 \times 10^6 \times 262{\cdot}8}{1728 \times 145{\cdot}7 \times \frac{72^3}{12^3}}$$

$$= 620 \text{ lb.} = 0{\cdot}277\,t$$

The component forces can now be determined as shown in Appendix II. Note also that δ' is practically equivalent to δ because $\cos\theta_p = 0{\cdot}997$.

As

$\delta' = 32{\cdot}5$ deg., $F_x = 620 \sin 32{\cdot}5 \cos 15{\cdot}5$

$= 320$ lb. $= 0{\cdot}143\,t$

and as

$\epsilon = 15{\cdot}5$ deg., $F_y = 620 \sin 32{\cdot}5 \sin 15{\cdot}5$

$= 90$ lb. $= 0{\cdot}04\,t$

$F_z = 620 \cos 32{\cdot}5$

$= 524$ lb. $= 0{\cdot}234\,t$

The bending moments at the various points in the piping system are:—

at A = 620 × 4·52 × 6 = 16,800 lb.-ft.
= 90 ton-in.

at C = 620 × 3·91 × 6 = 14,500 lb.-ft.
= 78 ton-in.

at D = 620 × 1·74 × 6 = 6,470 lb.-ft.
= 35 ton-in.

at B = 620 × 3·51 × 6 = 13,050 lb.-ft.
= 70 ton-in.

Table II below gives a comparison with the figures obtained by the " accurate " method.

From equation (16), the maximum longitudinal bending stress, f

$$= \frac{6 \times 16{\cdot}800 \times 12{\cdot}5}{262{\cdot}8}$$

= 4,800 lb. per sq. in., and occurs at A.

TABLE I. CALCULATION OF THE SECOND MOMENTS FOR EXAMPLE 1
(All lengths to be multiplied by R)

	Plan		Elevation		ΣY^2	True distance from thrust axis		Y_d	$(Y^2)_d$	L	3 M
	Y	Y^2	Y	Y^2		Y	Y^2				
A	1·78	3·17	4·16	17·3	20·47	4·52	92·4				
								4·12	92·3	5·19	116·2
a	0·4	0·16	0	0	0·16	0·4	0·06				
								0·8	1·67	1·51	3·2
b	0	0	1·2	1·44	1·44	1·2	1·73				
								2·71	58·27	3·3	70·9
C	0·84	0·71	3·82	14·6	15·31	3·91	60				
								3·07	59·4	7·16	138·5
c	0·84	0·71	0	0	0·71	0·84	0·59				
								0·895	4·66	2·84	14·8
D	0·84	0·71	1·52	2·31	3·02	1·735	5·25				
								0·035	0·33	1·27	12·0
d	0	0	1·77	3·14	3·14	1·77	5·58				
								1·74	37·9	$2{\cdot}64\sqrt{2}$	81·5
B	2·56	6·55	2·41	5·81	12·36	3·51	43·5				
										3 M =	437·1
										M =	145·7R^3

TABLE II

—	F	F_x	F_y	F_z	BM_A	BM_C	BM_D	BM_B
Proposed method	0·277	0·143	0·04	0·234	90	78	35	70
Accurate (bends considered) ..	0·268	0·12	0·031	0·236	102	59	25	63
Method (bends neglected)	0·291	0·136	0·034	0·256	106	81	28	69

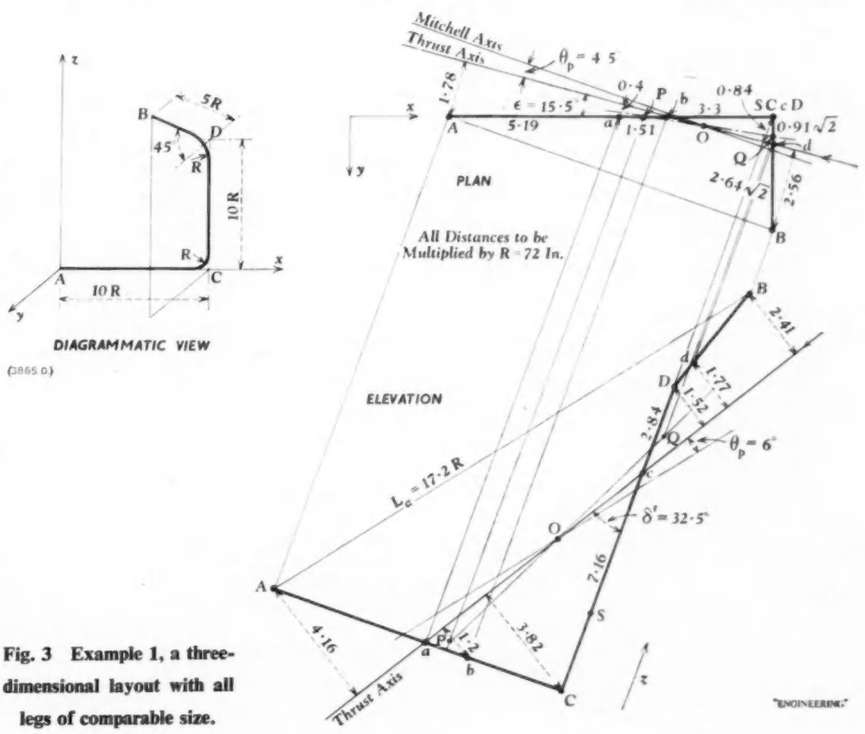

Fig. 3 Example 1, a three-dimensional layout with all legs of comparable size.

* Of Imperial Chemical Industries, Limited, Billingham Division.

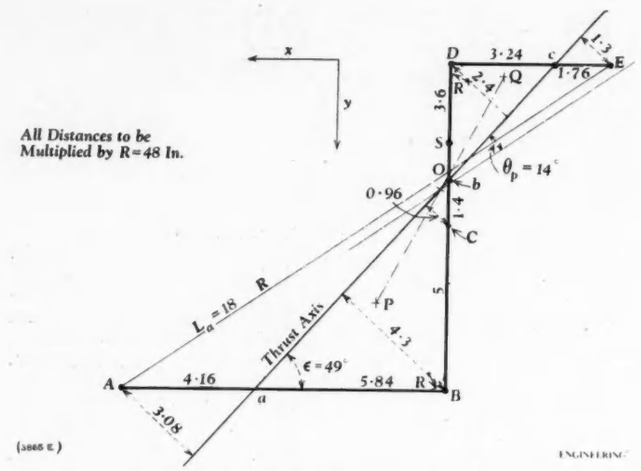

Fig. 4 Example 2, a two-dimensional layout.

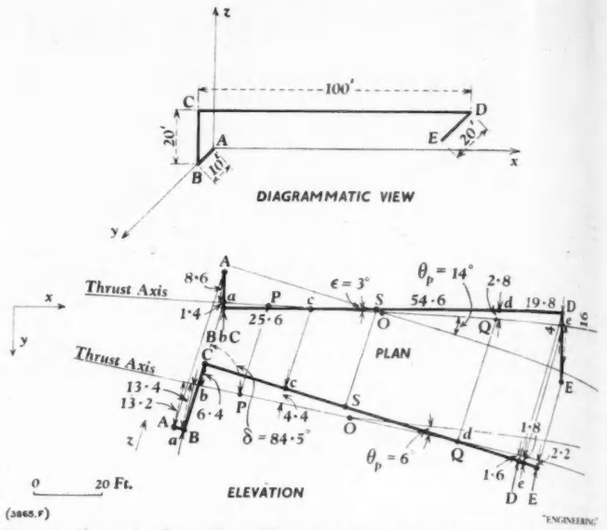

Fig. 5 Example 3, a three-dimensional layout where one leg of the pipe-line is far greater in length than the other effective elements.

(The " accurate " answer was found to be 5,420 lb. per sq. in.)

EXAMPLE 2

The two-dimensional pipe layout, incorporating different moments of inertia, shown in Fig. 4, forms the subject of the second example in which it is proposed to determine the equivalent stress.

Pipe Details:—Material, carbon steel

Pipe AC:

O/D = 14 in. $I = 952$ in.^{4}

$\lambda = 1·305$ $\therefore L_b = 0·0185R$

$t = 1·125$ in. $R = 48$ in. $= 4$ ft.

Pipe CE:

O/D = 10·75 in. $I = 315$ in.^{4}

$\lambda = 1·58$, $\therefore L_b$ is negligible

$t = 0·812$ in. $R = 48$ in. $= 4$ ft.

I/D = 9·126 in.

E (20 deg. C.) $= 29·8 \times 10^6$ lb. per sq. in.

T = 370 deg. C. $\therefore e = \frac{6·12 \text{ in.}}{100 \text{ ft.}}$ (Fig. 6).

E (390 deg. C.) $= 25·2 \times 10^6$ lb. per sq. in. (from Fig. 7).

$p = 330$ lb. per sq. in.

A cold pull-up of 66·67 per cent. is assumed.

Determination of Centre of Gravity:—

$$\frac{I_{10·75}}{I_{14}} = \frac{1}{3·02}$$

$\therefore$ Total equivalent length

$$= \left\{\frac{15}{3·02} + 10\right\} R = 14·96 R$$

$\frac{1}{2}$-length $= 7·48$ R

L.H. part A-S:

$$x' = \frac{\frac{10}{3·02} \times 5R}{7·48} = 2·21 \text{ R from B D}$$

$$y' = \frac{\left(\frac{5}{3·02} \times 2·5 + 2·52 \times (5 + 1·26)\right) R}{7·48}$$

$= 2·66$ R from A B

R.H. part, S-E:

$$x' = \frac{5 \times 2·5 R}{7·48} = 1·66 \text{ R from B D}$$

$$y' = \frac{2·48 \times 1·25 R}{7·48} = 0·41 \text{ from D E}$$

Second Moment:—The second moments of area are calculated in Table III.

From equation (22)

$$\Delta'' = L_a \times e = 18 \times 4 \times \frac{6·12}{100} = 4·4 \text{ in.}$$

From equation (23)

$$F = \frac{\Delta'' \cos \theta_p \times E \times I}{1{,}728 M} = \frac{4·4 \cos 14 \times 29·8 \times 10^6 \times 315 \times 0·667}{1{,}728 M}$$

(*a*) If the equivalent additional lengths of the bends are neglected,

$M = 43·9 R^3 = 43·9 \times 4^3$ ft.$^3 = 2{,}810$ ft.^{3}

Therefore F = 5,500 lb. (5,740)*

(*b*) If the equivalent additional length of the bends are included,

$M = 43·9 R^3 + L_b \times Y_B^2 = 43·9 \times R^3 + (0·018 \times 48 \text{ in.}) \times 18·5 R^2$ ft.^{3}

and M = 3,065 ft.^{3}

Therefore F = 5,070 lb. (5,740)*

* The figures in brackets are the "accurate" answers with bends ignored.

Table III. Calculation of the Second Moments for Example 2

	Y	Y^2	Y^3	L	Y_d	$(Y^3)_d$	3 M
A	3·08 R	—	$29·3R^3$				
				$4·16 \times \frac{1}{3·02}$	3·08	29·3	$13·1R^3$
a	0	—	0				
				$5·84 \times \frac{1}{3·02}$	4·3	79·8	35·9
B	4·30	18·5	79·8				
				$5·0 \times \frac{1}{3·02}$	3·34	78·88	39·1
C	0·96	—	0·88				
				1·4	0·96	0·88	1·3
b	0	—	0				
				3·6	2·4	13·8	20·7
D	2·4	5·76	13·8				
				3·24	2·4	13·8	18·6
c	0	—	0				
				1·76	1·3	2·2	2·98
E	1·3	—	2·2				
							$131·7 R^3$
							$M = 43·9 R^3$

Using the larger value of F (5,500 lb.):—

Component Forces

$\epsilon = 49$ deg.

$F_x = 5{,}500 \cos 49 = 3{,}600$ lb. (3,600)

$F_y = 5{,}500 \sin 49 = 4{,}170$ lb. (4,480)

Moments

$M_A = 5{,}500$ lb. $\times 3·08$ R $= 67{,}800$ lb.-ft. (86,000)

$M_B = 5{,}500$ lb. $\times 4·3$ R $= 94{,}600$ lb.-ft. (92,800)

$M_D = 5{,}500$ lb. $\times 2·4$ R $= 52{,}800$ lb.-ft. (51,000)

$M_E = 5{,}500$ lb. $\times 1·3$ R $= 28{,}600$ lb.-ft. (38·400)

Stresses

From equation (16), the longitudinal bending stress, *f*, at B:

$$f = \frac{6 \times 94{,}600 \times 14}{952} = 8{,}350 \text{ lb. per sq. in.}$$

Longitudinal bending stress at D:

$$f_b = \frac{6 \times 52{,}800 \times 10·75}{315} = 10{,}800 \text{ lb. per sq. in.}$$

Equivalent stress at D (hot state) (see Appendix I)

Longitudinal stress due to

(*a*) bending $= f_b \times \frac{33·33}{66·67} \times \frac{25·2 \times 10^6}{29·8 \times 10^6}$

$= 4{,}570$ lb. per sq. in.

(*b*) steam pressure $f_{p1} = \frac{p \times D_i}{4t}$

$= 330 \times \frac{9·126}{4 \times 0·812} = 927$ lb. per sq. in.

$\therefore P_1 = 5{,}497$ lb. per sq. in.

Transverse stress due to

(*a*) steam pressure $f_{p1} = \frac{p \times D_i}{2t}$

$f_{p2} = P_2 = 1{,}854$ lb. per sq. in.

$\therefore$ the equivalent stress $f_e = \sqrt{P_1^2 + P_2^2 - P_1 P_2}$

$= \sqrt{23{,}440{,}000}$

$= 4{,}840$ lb. per sq. in.

EXAMPLE 3

The third example, see Fig. 5, concerns a three-dimensional pipe layout where one pipe length is very much greater than the remainder so that the thrust axis can be taken as coincident with the centre of gravity axis.

Pipe Details:—Material, carbon steel

O/D = 14 in. I = 952 in.⁴ $\lambda = 1{\cdot}305$

$t = 1{\cdot}125$ in. R = 48 in.

E (cold) = $29{\cdot}8 \times 10^6$ lb. per sq. in.

T = 370 deg. C.

Therefore $e = 6{\cdot}13$ in. per 100 ft. (Fig. 7), Assume 100 per cent. cold pull-up.

Determination of Centre of Gravity:—

Total L = 150 ft. ½-length = 75 ft.

Section A-S:

$$x' = \frac{45 \times 22{\cdot}5}{75} = 13{\cdot}5 \text{ ft. from A B}$$

$$y' = \frac{10 \times 5}{75} = 0{\cdot}7 \text{ ft. from C D}$$

$$z' = \frac{20 \times 10 + 10 \times 20}{75} = 5{\cdot}33 \text{ ft. from C D}$$

Section S-E:

$$x' = \frac{55 \times 27{\cdot}5}{75} = 20{\cdot}4 \text{ ft. from D E}$$

$$y' = \frac{20 \times 10}{75} = 2{\cdot}67 \text{ ft. from C D}$$

$z' = 0$ from C D

Second Moment:—The calculation of the second moments are given in Table IV.

From equation (22), the expansion is given by

$$L_a \times e = 106 \text{ ft.} \times \frac{6 \text{ ft. } 13 \text{ in.}}{100 \text{ ft.}} = 6{\cdot}5 \text{ in.}$$

From equation (23),

$$F = \frac{6{\cdot}5 \times \cos 14 \times \cos 6 \times 29{\cdot}8 \times 10^6 \times 952}{1{,}728 \times 6{,}467} = 15{,}900 \text{ lb.}$$

Component Forces (see Appendix II)

as $\delta = 84{\cdot}5$ deg., and $\epsilon = 3{\cdot}0$ deg.

$F_x = 15{,}900 \times \sin 84{\cdot}5 \times \cos 3{\cdot}0 = 15{,}800$ lb.

$F_y = 15{,}900 \times \sin 84{\cdot}5 \times \sin 3{\cdot}0 = 826$ lb.

$F_z = 15{,}900 \times \cos 84{\cdot}5 = 1{,}520$ lb.

Moments

at A = $15{,}900 \times 15{\cdot}75 = 251{,}000$ lb.-ft.

B = $15{,}900 \times 13{\cdot}47 = 214{,}000$ lb.-ft.

E = $15{,}900 \times 16{\cdot}15 = 257{,}000$ lb.-ft.

Table V illustrates the greater accuracy of this modified method. With the exception of the bending moment at one of the anchor points, which is over-estimated, very much better agreement is obtained by means of the modified method.

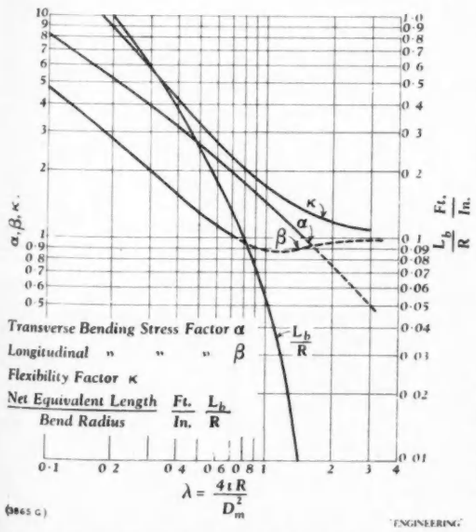

Fig. 6 Flexibility and stress coefficients for plain bends and the equivalent lengths of the bends.

TABLE IV—Calculation of the Second Moments for Example 3

—	Plan Y	Plan Y²	Elevation Y	Elevation Y²	ΣY²	True distance from thrust axis Y	True distance from thrust axis Y²	Y_d	$(Y^2)_d$	L	3M
A ..	8·6	74	13·2	174	248	15·75	3,900	2·35	1,490	8·6	5,450
a ..	0	—	13·4	—	180	13·4	2,410	181 × 3 × 1·4			760
B ..	1·4	1·96	13·4	180	182	13·47	2,450	12·07	2,447	13·5	2,740
b ..	1·4	—	0	—	—	1·4	2·75	5·15	279	6·5	352
C ..	1·4	1·96	6·4	41	43	6·55	282	2·15	197	25·6	2,340
c ..	0	—	4·4	—	—	4·4	85	1·6	63	54·6	2,150
d ..	2·8	—	0	—	—	2·8	22	1·5	58	19·8	766
D ..	4	16	1·6	2·56	18·56	4·3	80	2·5	74	4	119
e ..	0	—	1·8	—	—	1·8	5·85	14·35	4,224	16	4,720
E ..	16·0	256	2·2	4·84	261	16·15	4,230			3M =	19,400
										∴ M =	6,467

TABLE V

	F	F_x	F_y	F_z	BM_A	BM_B	BM_E
Modified method	15,900	15,800	826	1,520	251	214	257
Accurate method	16,100	16,000	1,085	1,600	127	196	245
Proposed method	11,330	11,060	1,950	1,580	127	147	123

APPENDIX I

Equivalent Stress

For ductile materials, it is generally accepted that the maximum shear-strain energy theory provides the most suitable basis for deriving the single simple stress equivalent to any given state of stress at a cross-section of a pipe. The equivalent simple stress so evaluated can then be used for comparison with the criterion of allowable working stress.

Longitudinal Stress, P_1:

(*a*) Due to bending, $f = F\,Y\,\frac{6\,D_o}{I}$, or

$f_b = \beta\,F\,Y\,\frac{6\,D_o}{I}$ in the case of pipe bends.

(*b*) Due to steam pressure, $f_{p1} = P\,\frac{D_i}{4\,t}$.

(*c*) The stress due to pure compression can usually be neglected, therefore $P_1 = f + f_{p1}$ or $f_b + f_{p1}$.

Hoop Stress, P_2:

(*a*) Due to steam pressure, $f_{p2} = P\,\frac{D_i}{2\,t}$, therefore, $P_2 = f_{p2}$.

Radial Stress, P_3: Usually negligible.

Shear Stress: Indeterminable with the proposed method without some additional calculations, which are not justifiable, as in general the shear stresses are small. Furthermore, this small loss is to some extent compensated by the fact that the longitudinal bending stress is over-estimated, as in most cases the thrust axis will not be in the plane of the bend.

Therefore the equivalent stress is given by:

$$f_e = \sqrt{P_1^2 + P_2^2 - P_1 P_2}.$$

APPENDIX II

Resolution of Thrust Force

Let the vector O P represent the thrust force F given by the polar co-ordinates (F, δ, ϵ), as shown in Fig. 9, page 558.

Draw P N perpendicular to the X O Y-plane and N S perpendicular to O X, then O S = component of the thrust axis in the X-direction = F_x.

and similarly S N = F_y, and NP = F_z.

With the angle N P O = angle Z O P = δ,

and the angle X O N = ϵ, it follows that

F_x = O N cos ϵ = O P sin δ cos ϵ = F sin δ cos ϵ

F_y = O N sin ϵ = O P sin δ sin ϵ = F sin δ sin ϵ

and

Fz = OP cos δ = F cos δ.

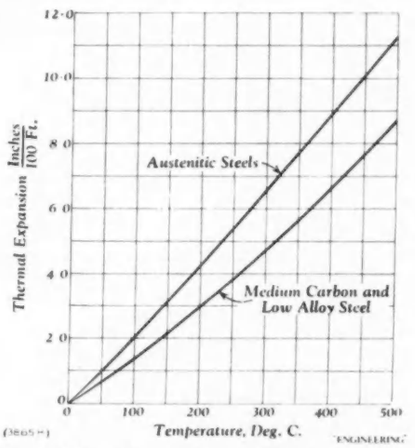

Fig. 7 Thermal expansion coefficients for pipe-lines.

The curves are based on the mean values of the linear expansion coefficients (α) given in the Billingham Division (I.C.I.) D.D. book, Section A2.

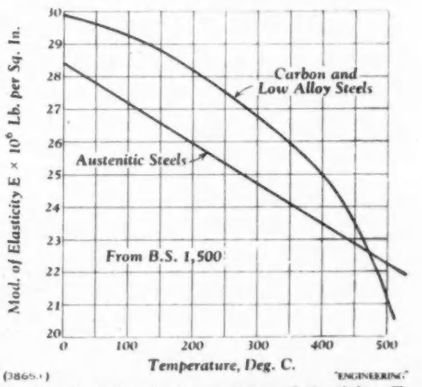

Fig. 8 Variation in the modulus of elasticity, E_t for pipe-line steels, from B.S.1,500 (1943).

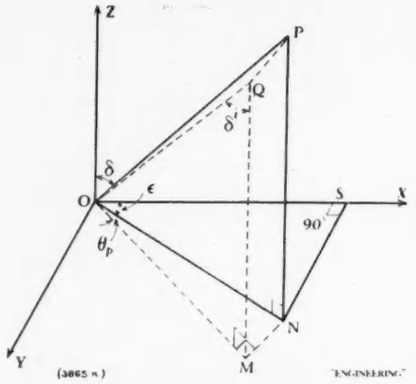

Fig. 9 Resolution of thrust forces defined by polar co-ordinates. See Appendix II, page 557.

When following the method proposed in this article, the elevation will be drawn in a plane which is perpendicular to the X O Y-plane, but in general will not intersect the latter in the line O N. The actual line of intersection O M will make an angle θ_p with O N. (θ_p = angle between thrust axis and a line joining the anchors in the plan view).

It will now be shown that even if the angle θ_p attains as high a value as 15 deg. (cos 15 = 0·966), the accuracy of the final answers will not be adversely affected by simply reading off δ' from the elevation drawing. Since

$$\tan \delta' = \frac{OM}{MQ}$$

as

$$OM = ON \cos \theta_p = OP \sin \delta \cos \theta_p$$

and

$$MQ = NP = OP \cos \delta.$$

Therefore $\tan \delta' = \tan \delta \cos \theta_p = \tan \delta$ approximately, when θ_p is small (< 15 deg.), or in words, the angle δ' which is the angle between the thrust axis and the Z-axis in the suggested elevation drawing is not materially different from the angle δ, which is the angle between the thrust axis and the Z-axis, if the elevation had been drawn parallel to the projection into the X Y-plane of the thrust axis, provided that θ_p is small (< 15 deg.).

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To mark the occasion of Sir Alfred Herbert's 90th birthday and in recognition of his outstanding services to the industry, the Machine Tool Trades Association, Victoria House, Southampton-row, London, W.C.1, have instituted a scholarship to assist engineering students in the prosecution of their studies. This award, of the annual value of about £125, is designed to enable students of Coventry Technical College to widen their knowledge of machine-tool design and manufacture. Further particulars are available from the Association.

MAINTAINING GEAR-CUTTING ACCURACY

TESTING HOBS AND FINISHED GEARS

Two new machines of interest to gear manufacturers, which have been developed by W. Klingelnberg Söhne, Remscheid, Germany, are now being marketed in Great Britain by the sole agents, the Sykes Machine Tool Company, Limited, The Hythe, Staines, Middlesex.

HOB TESTING

Since hob sharpening errors are a particular source of gear tooth profile inaccuracies, the logical place to start hobbed gear inspection is with the hob, and the machine shown in Fig. 1 has been designed for this purpose. It is suitable for hobs from 2½ in. to 10 in. diameter and 1¼ to 10 diametral pitch. The distance between the work head centres is variable up to 18½ in. The maximum base lead angle is 40 deg., the maximum base circle diameter 3⅛ in., and the maximum height of lead measured 6¼ in. An infinitely-variable speed motor drive enables the hob to be rotated through a maximum of six revolutions during testing, at a speed of from 1 to 7 r.p.m. The operations for which the machine is suitable include testing the hob spiral for lead, gash spacing and flank profile; checking the flute spacing and flute lead, true running over tooth crests, and cutting face profile errors; gauging concentricity and axial slip of the register; and thread-spacing on multi-start hobs.

The measuring-head column of the machine is equipped with a gauging head and electronic stylus unit, and the test values are chart-recorded automatically with variable magnification up to 500 to 1.

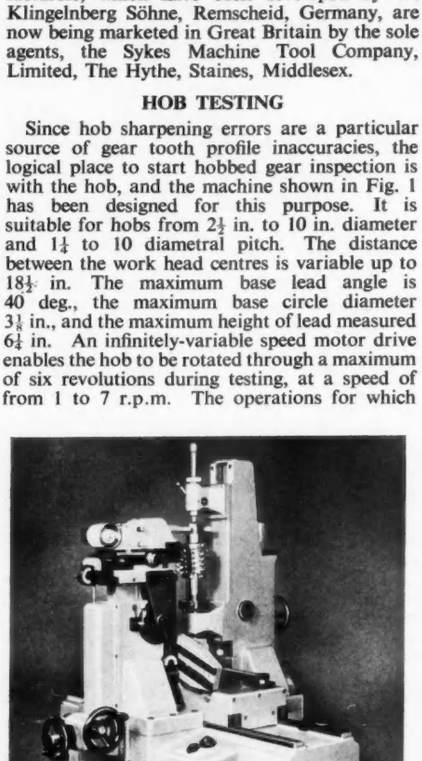

Fig. 1 The Klingelnberg hob tester covers the whole range of necessary tests on hobs from 2½ in. to 10 in. diameter.

Fig. 2 Gears which are too large for existing stationary equipment can be tested with this machine, which is mounted on the gear itself.

TESTING LARGE GEARS

Profile tests on the tooth flanks of involute or helical gears too large for existing stationary equipment can be carried out on a machine, shown in Fig. 2, which is designed for mounting on the gear to be tested. Three models of this machine are available; for gears of 24 in. to 47 in. outside diameter and coarsest pitch 1¾ D.P., for diameters 47 in. to 106 in. and coarsest pitch 1¼ D.P., and for 106 in. to 235 in. and ¾ D.P. Gears of 15 to 25 deg. normal pressure angle, and helicals up to 45 deg. can be accommodated.

The machine consists of a bridge equipped with ball-bearing mounted rollers running on the gear face, and on the reference register, which may be the gear bore or some other surface machined for the purpose. The register must be concentric with the gear axis, but the surface-finish requirements are not too exacting; a smooth surface turned with a fine finish is adequate. The bridge is supported by a tubular frame in the form of an isosceles triangle, which is expanded by springs and set according to the gear diameter. The frame also runs on rollers on the gear face and in the register, so that the bridge is held parallel with the gear face and guided in a circle concentric with the gear axis. The measuring equipment includes a stylus, which can be mounted to suit the type of test required, and an electric-spark recorder, where inaccuracies are shown at magnifications of 50, 100, 250 or 500 to 1.

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METALLURGICAL REVIEW

The first issue of a new quarterly publication, *Metallurgical Reviews*, has recently made its appearance. The periodical which is published by the Institute of Metals, 17 Belgrave-square, London, S.W.1, will contain "authoritative, critical and interpretative reviews of knowledge in various fields of interest to metallurgists." The reviews are to be written for the non-specialist and will cover the whole field of metallurgy, except mining, the extraction of metals from their ores, and iron and steel works practice. The quarterly is obtainable only by annual subscription, the rates being £1 12*s.* 6*d.*, post free for members of the Institute, and £2 2*s.*, post free, for non members.

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The Mobil Oil Company, Limited, Caxton House, London, S.W.1, have added two new black-and-white 16 mm. sound films to their European Industrial Film Library, each running for 30 minutes. "Hydraulic Systems," shows how energy can be transmitted by fluid pressure, and demonstrates various types of pumps and valves used in hydraulic transmissions.

"Diesel Engine Lubrication" begins with simple illustrations of the various Diesel engine cycles, of supercharging and fuel injection, but the main purpose of the film is to demonstrate what is required for effective Diesel lubrication, and how the additive types of oils can provide it.

GAS LUBRICATED BEARINGS

DESIGN, MANUFACTURE, APPLICATION

Gas lubrication, which has recently undergone considerable development under the stimulus of the atomic energy programme, may well have applications to half a dozen other branches of engineering, and this is borne in mind by the authors of a paper "Principles and Applications of Hydrodynamic-Type Gas Bearings," presented at the Institution of Mechanical Engineers on October 26. The authors, Mr. G. W. K. Ford, M.B.E., Mr. D. M. Harris and Mr. D. Pantall, are all members of the United Kingdom Atomic Energy Authority. The call for gas bearings arose from the need to install moving parts within enclosed gas circuits where contamination of the gas is undesirable, the parts themselves are largely inaccessible and the formation of oxide films is impossible; this occurs in gas-cooled reactors such as those at Calder Hall. In addition, pumps for liquid metals, which may be at high temperatures, require a lubricant that does not deteriorate under the action of heat and will not contaminate the metals being pumped; bismuth, which may serve as a solvent for nuclear fuels in future reactors, is chosen by the authors as an example. However, high temperatures, gas circuits, inaccessibility, particulate matter in suspension, and the need to exclude contaminating materials are requirements not unique to atomic engineering. To place gas bearings in the context of other applications, the authors outline their features and limitations, and name some other fields of engineering—machine tools and chemical industry for example—in which they may be used. The paper is concerned mainly with hydrodynamic as distinct from hydrostatic bearings and covers both thrust and journal types. Parts of it are reprinted below, but specialised data and calculations are omitted.

HYDROSTATIC OPERATION

There are numerous specialised circumstances in which it may be impracticable to employ bearings lubricated by liquids or greases, and where dry-rubbing bearings are inadequate. In these cases it is sometimes practicable to use a gas to lubricate the bearing system.

There are two basic classes of gas-lubricated bearings of both journal and thrust types, namely hydrostatic, and self-acting or hydrodynamic. The paper discusses both practical development work and fundamental investigation of bearing properties found necessary in developing a number of successful small machines for auxiliary duties in the atomic energy programme. The practical work reported was carried out by the authors and their colleagues at the Atomic Energy Research Establishment (A.E.R.E.), Harwell.

In hydrostatic bearings the load is sustained by the hydrostatic gas pressure in the clearance space between the two elements of the bearing. There is always a finite outward leakage of gas which must be replaced by gas pumped from an external source through feed holes in the bearing wall. The pumping power thus consumed will increase roughly as the cube of the bearing clearance. In any application of hydrostatic bearings, not only must this pressure source be provided, but, in addition, suitable provision must be made to dispose of the exhaust gas. In some applications in which self-acting gas bearings are employed for normal running conditions it is found advantageous to use an external pressure source for starting and stopping, so that the bearing is temporarily of the hydrostatic type. Such jacking is required in applications involving very high stationary bearing loads or in which only a small starting torque is available.

HYDRODYNAMIC ACTION

The self-acting bearing generates its own hydrostatic pressure within the clearance space, by virtue of the viscosity of the fluid in which it is immersed and the relative motion of the bearing elements. The simplest types in this category are, firstly, the tilted-pad thrust bearing, usually consisting of a flat rotating plate and one or more flat pads slightly inclined to the direction of motion, and secondly, the plain journal bearing consisting simply of a plain smooth shaft rotating within a plain smooth bearing bush. So far as journal bearings are concerned, the research and applications described in this paper refer to plain journals of this type, but the thrust bearings have usually been of a somewhat different pattern utilising a special form of grooving in one of a pair of flat discs to provide the viscosity-induced pressure-generating action, rather than the somewhat more mechanically complicated, but hydrodynamically simpler, inclined-pad bearing.

Although self-acting gas bearings, which are known to have been considered as long ago as 1854, have not received much attention for application to machines up to the present time. the authors' experience has shown that self-acting bearings adequate for many practical purposes can readily be made using simple and commonly available equipment. Machines so fitted can be made very reliable and long-lived, and can be designed to operate over a wide range of ambient pressures and temperatures in almost any gas and over a considerable range of sizes.

STATIC AND DYNAMIC LOADS

Because static loads increase as the cube of linear dimensions, and dynamic loads as the fourth power, whereas bearing strengths increase only as the square of linear dimensions, the difficulties of using gas bearings will increase as the absolute size of the machine increases. In practice, this means making the bearings disproportionately larger as the absolute size of the machine grows. Nevertheless, machines of some 100 h.p. do appear to be feasible with self-acting gas bearings of reasonable size. Experiments on journal bearings carried out by the authors have ranged from 1 in. in diameter up to 7 in., but only limited work has been done on machines with larger than 2 in. diameter bearings. Fig. 1 shows a demonstration machine using two bearings each of 14 in. in effective length and 7 in. in diameter. The shaft weighs 300 lb., and runs self-acting in air at atmospheric pressure at speeds between about 100 r.p.m. (at which it first touches on slowing down) to 3,000 r.p.m., the fastest so far achieved. It is expected to carry a total load of one ton at atmospheric pressure at 3,000 r.p.m. with a minimum operating clearance of 0·0007 in. Jacking air is used for starting because of the low torque available in this experimental machine, but it can coast to rest without jacking air with negligible damage to its surfaces. The diametral clearance is about 0·0045 in. The cast-iron shaft was ground on a normal grinding machine with no subsequent finishing operations, and the cast-iron bearing sleeves were honed by normal cylinder-liner techniques.

The design and constructional approaches which it is necessary to employ in gas-bearing machines differ considerably from the conventional methods employed with oil-lubricated bearings, and must be properly recognised before a successful machine can be designed. In particular, in many applications the performance of a self-acting gas-bearing cannot be predicted from liquid-bearing theory with sufficient accuracy for design purposes because of compressibility effects. It is these differences to which this paper is mainly devoted.

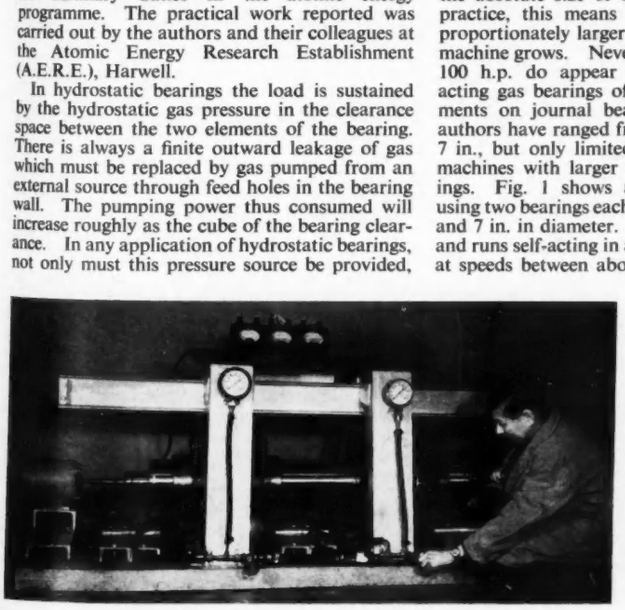

Fig. 1 Experimental machine incorporating gas journal bearings 7 in. in diameter. The bearings are of self-acting pattern but jacking air is used for starting.

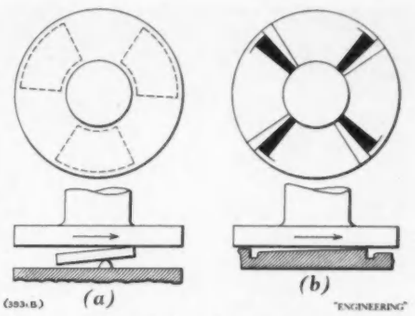

Fig. 2 Tilting pad (a) and fixed pad (b) thrust bearings.

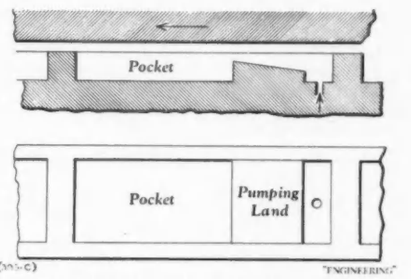

Fig. 3 Hydrodynamic pocket thrust bearing.

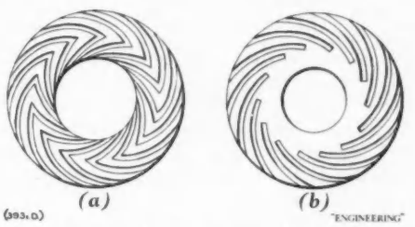

Fig. 4 Grooved thrust bearings: (a) herring-bone grooved and (b) spiral grooved.

VISCOSITY AND BEARING SIZE

The viscosity of lubricating liquids may be a thousand times greater than that of gases, and consequently the load capacity of a given self-acting bearing will be of the order a thousand times greater when operated on a liquid such as lubricating oil than when operated on a gas. If the gas bearing is operated at low ambient pressures it will be even weaker. This means that for a given machine a self-acting gas bearing must in principle be correspondingly larger than the liquid bearing required to do the same job.

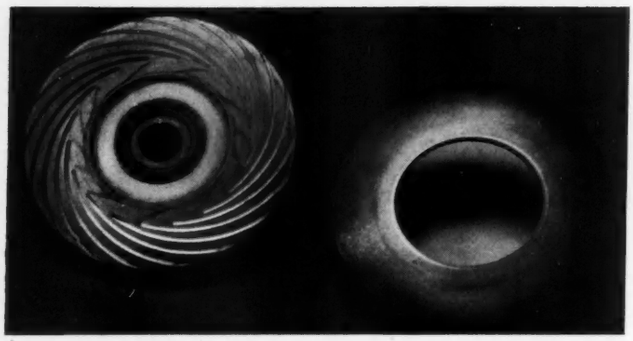

Fig. 5 Spiral-groove thrust plates after 20,000 starts and stops in a liquid-metal pump. The ungrooved stationary member is made of carbon.

However, in small machines using conventional bearings it will usually be found that considerations of shaft stiffness and strength lead to journal bearings which are much larger in diameter than would be chosen on theoretical grounds for the bearing performance required, and this results in liquid bearings on most small machines having an unfavourably small length-to-diameter ratio, often less than 1 to 1. Thus the ratio of power wasted in friction to load carried is also unfavourable, but such bearings can easily be made to provide a very large safety factor on load capacity, and their short length eases questions of alignment and running-in. By so constructing gas journal bearings, in combination with self-aligning mountings, that they have the most favourable practical length-to-diameter ratio, which in practice lies between 2 to 1 and 4 to 1, being governed by manufacturing and structural considerations, it happens that in small machines the required journal bearings are compact enough to be practicable, though, in general, somewhat larger in diameter than the corresponding liquid or ball bearing, and occupying a considerably greater length of shaft. As the machines grow in absolute size, so the disproportion increases. Rather similar reasoning applies to thrust bearings, and it will be evident that it is essential when designing gas-bearing machines to reduce static and dynamic loads on both journal and thrust bearings to an absolute minimum.

An important practical difference between self-acting gas and oil bearings is that gases have no boundary lubrication properties. This means that the final alignment of bearings by means of the deformations normally permitted during the running-in of machines fitted with oil-lubricated plain bearings cannot be contemplated for gas bearings. Consequently, the gas bearing elements themselves must be made to the accuracy required for final operation, and in multi-bearing machines it is almost essential to mount the bearings in self-aligning mountings. Further, the metals chosen for journal and bearing must be such as to reduce galling during rubbing contact to minimise damage during starting and stopping, or during shock overloading or periods of accidental contact.

In this connection, it is of interest to recall that with self-run-in oil bearings it is generally accepted, and demonstrated by experiment, that touching of some part of journal and bearing is nearly always present in all conditions of running, even though the lubrication is predominantly hydrodynamic. It is found that in gas bearings produced by standard honing techniques, no touching occurs during normal running. Even so, it is also found that should intermittent metallic contact occur due to an error in manufacture or assembly, or to an overload, a remarkable amount of rubbing, even at high speeds, can be tolerated if the metals used have been chosen for good anti-galling properties.

IMPROVEMENT WITH TEMPERATURE

One of the peculiarities of self-acting gas bearings is that their performance improves with increase of temperature owing to the corresponding increase in gas viscosity, the reverse being so with liquid lubrication, in which vaporisation or decomposition are also serious problems at high temperatures. Provided, therefore, that proper precautions are taken in selecting materials and suitable heat-treatment is carried out during manufacture so as to guard against distortion and differential expansion of shaft and bearing shell, the operation of bearings at quite high temperatures can be considered. For example an experimental machine, consisting of an electric motor supported by two 2 in. diameter journal bearings, has been running at Harwell for some time in a general ambient temperature of 400 deg. C. (752 deg. F.), with an increase to 500 deg. C. (932 deg. F.) scheduled shortly. If it is desired to operate self-acting gas bearings at low temperatures the loss of strength due to the decreased viscosity must be taken into account.

For a given bearing strength and associated frictional heat-production rate, a gas bearing has a much larger diameter and length than a liquid bearing, the former easing the problem of providing sufficient shaft stiffness, whilst the consequent larger surface area for the given rate of heat production also greatly facilitates cooling the bearing, so that in the majority of cases natural convection is sufficient. This property may be used to advantage for machines required to operate at very high speeds. In such applications, liquid-lubricated bearings must be a compromise between the small size required to provide sufficient bearing strength and at the same time to keep the heat production small, and the relatively large diameter needed to provide adequate shaft stiffness. For example, a 2 in. diameter air bearing with 0·001 in. diametral clearance has been operated satisfactorily in the open air at a speed of over 60,000 r.p.m. with natural convection cooling only.

PRESSURE AND COMPRESSIBILITY

When self-acting gas bearings are working in a compressible regime there is a fundamental difference, compared with liquid-lubricated bearings, in their efficiency. To illustrate this, consider the case of a journal bearing operating at a fixed eccentricity and the effect of reducing the ambient pressure. As the ambient pressure falls, the pressure ratio (that is, ratio of maximum pressure in the bearing to the ambient pressure) rises, and the load carried falls off due to compressibility effects, becoming in the limit zero for zero ambient pressure. On the other hand, the friction losses remain almost constant, so that the efficiency of a self-acting gas bearing as measured by its coefficient of friction, or ratio of power wasted to load carried, progressively deteriorates with fall in ambient pressure.

The hydrodynamic behaviour of gas bearings differs from that of liquid bearings only when the pressure ratio is significant. Thus if the pressure rise within the bearing is less than, say, 10 per cent. of the ambient pressure, the performance of the bearing may be predicted with an accuracy quite sufficient for practical application using normal liquid-bearing theory. This is the maximum attainable performance, which compressibility effects will reduce. The considerable difference between the characteristics of gas and liquid bearings when the pressure ratio is significant depends upon the fact that gas density alters with the changes in pressure around the bearings, causing changes in both the shape and magnitude of the pressure distribution and, in consequence, altered load capacity properties.

THRUST BEARINGS

All the normal types of hydrodynamic thrust bearing as commonly used with liquid lubricants may be used with gases. In the case of the pivoted-pad type, as illustrated in Fig. 2*a*, it is necessary to take account of compressibility effects when determining the position of the pivot points. As ambient pressure falls, the centre of pressure moves to a position nearer the trailing edge of the pad, and so likewise must the position of the pivot point. A disadvantage of the pivoted-pad type of bearing when used with gases is that the pivots need extremely accurate setting because of the smaller running clearances usually necessary when gases are used instead of liquids for lubricating practical machines. Alternatively, a system of load-equalising levers and pivots may be employed, or, if the axial setting of the thrust bearing may be allowed to move, spring-loaded pads.

There are, however, other types of thrust bearing, which are found to be satisfactory for use with gases, which avoid this difficulty. One is the fixed inclined-pad bearing as shown in Fig. 2*b* and its logical development, the hydrodynamic pocket bearing, as shown in Fig. 3. Yet another form is illustrated in Fig. 4, in which constant-depth grooves are cut into the surface of a circular plate. The bearing on the right was used in machines described in the paper.

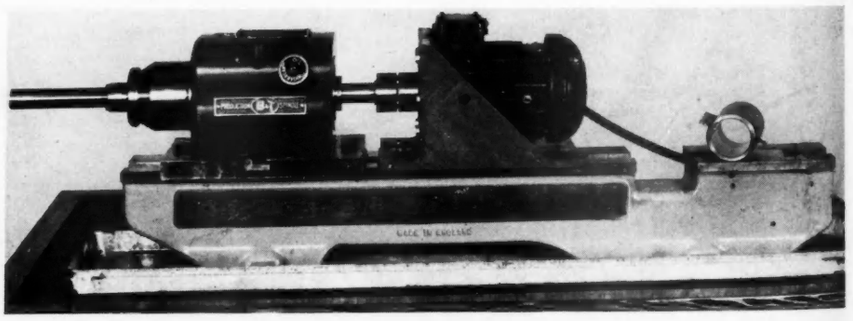

Fig. 6 Motor and grinding spindle used in tests, showing quill in position. Other applications for gas-lubricated bearings include wind-tunnel balances, gyroscopes, dynamometers, centrifuges, gas compressors, liquid-metal pumps and chemical engineering generally.

The spiral-groove bearings were found to perform well in accord with theoretical prediction; the only apparent discrepancies were caused by plate distortion under load. They have proved to be easy to make and reliable in service. The fixed plate is fitted on a ball-pivot gymbal mounting to provide self-alignment. Both plates are lapped optically flat. Either the fixed or the moving plate may carry the grooving, but in machines in which a carbon member is employed as one of the bearing element pairs, it is preferable to make this the fixed element, having a plain

surface, and to cut grooves in the rotating metal plate, as shown in Fig. 5.

VIRTUES OF GAS BEARINGS

Gas bearings, either hydrostatic or hydrodynamic, appear to have advantages over liquid or grease lubricated types in a number of special circumstances. Specially noteworthy is the avoidance of contamination by liquid lubricants of the gas surrounding the rotating system, their ability to operate over a wide range of pressure and temperature, and their suitability for use in nuclear radiation fields. In particular cases their simplicity, quietness, reliability, low friction and long life may offer special benefits.

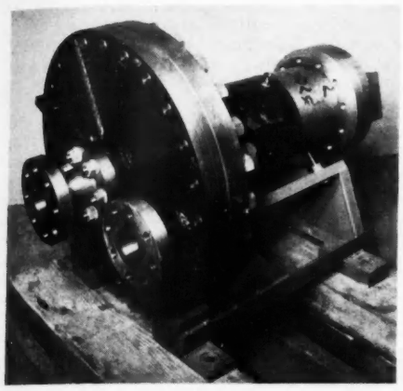

Fig. 7 Carbon dioxide circulator before installation and lagging. Carbon dioxide is used in some nuclear reactors to transfer heat from the fuel elements to external heat exchangers. The gas may be at a pressure of 100 lb. per sq. in.

AND WHEN TO USE THEM

As a rough guide, when considering which type of gas bearing to use, it can be taken that hydrostatic gas bearings should be considered where gas lubrication is required under high load at low or zero speed, or for very low temperature applications, when the viscosity of gases is rather small. Pressure feed may also allow the use of bearings smaller in size than the self-acting type, and may therefore result in an acceptable bearing size in cases where the conditions would otherwise lead to an excessively large self-acting bearing. They also can employ less accurately machined components since they are separated by the pressure gas before start-up and may be run at large operating clearances provided sufficient pumping power may be expended. One important field of application is to provide low friction bearings for such devices as wind tunnel balances, gyroscopes and dynamometers, but there are also numerous well known high-speed applications appropriate to special circumstances, such as centrifuges and grinding spindles. Fig. 6 shows equipment employed in tests carried out by the authors, in which use was made of a grinding spindle.

Conversely, self-acting bearings are necessary if no source of pressure gas can be made available or the exhaust cannot be disposed of, or if the power available for pumping a supply of pressure gas is insufficient. The advantage of requiring no auxiliary equipment, unless jacking is needed, is also noteworthy.

COMPRESSORS

The most obvious application for gas-lubricated bearings would seem to be gas-handling machinery, in particular gas compressors and circulators or possibly complete gas turbines. One particularly interesting and suitable application of this type is the circulator gas pump shown in Figs. 7 and 8, and used to circulate oil-free carbon dioxide at a mean pressure of 100 lb. per sq. in. gauge at about 150 deg. C. (300 deg. F.) through an experimental high-temperature cooling circuit in a nuclear reactor at Harwell. The speed of this unit in operation may vary from 2,000 to 13,000 r.p.m., being driven from a variable-frequency three-phase alternator. The impeller is carried at one end of a hollow shaft which runs in two self-aligning, self-acting gas-bearings, the relatively heavy induction-motor squirrel-cage being placed between the bearings. The journal bearings are 5 in. in length and 2 in. in diameter, and have a mean diametrical clearance of 0·0012 in. The shaft and rotating thrust plate are of chromium-plated nickel alloy and the bearings and stationary thrust plate are of a cast nickel alloy, a combination chosen to give freedom from corrosion, good anti-galling properties, similar thermal expansion of shaft and bush, and low thermal conductivity along the shaft. This limits the transfer of heat along the shaft from the impeller to the motor unit. In general, everything is done to keep overhangs beyond the bearings as small as practicable, because of the double effect of the increasing difficulty of keeping overhanging weights concentric and free from relative movement due to distortion and other causes, and the correspondingly large moment arm through which forces arising from such defects are applied to the bearing. The short overhang of the impeller provided in this machine is designed to reduce conduction of heat from the impeller to the bearing, in order to avoid differential expansion of the bearing elements.

In general, it is considered that any gas which can be physically contained in a material enclosure can also be used to lubricate a machine provided only that it is not so rarefied as to provide no lift, nor so near its condensation point as to condense within the high-pressure regions of the bearings. There would thus seem to be considerable application possibilities in the field of chemical engineering.

SEALED LIQUID PUMPS

The combination of poor electrical conductivity, particulate matter in suspension, high temperature and high level of radioactivity together with requirements for very long life and negligible leakage may make impracticable or uneconomic the use of pumps of submerged bearing or shaft-seal rotary pattern, the electromagnetic types, or reciprocating pumps using pistons or flexible diaphragms.

An example is the pumping of liquid lead or bismuth at about 400 deg. C. (752 deg. F.) containing a nuclear fuel such as uranium in solution or a fertile material such as thorium oxide in suspension. Fig. 9 illustrates a laboratory-scale liquid pump using gas-lubricated bearings now being developed at Harwell, which meets this difficult combination of conditions. This machine is largely similar to the carbon dioxide circulator in general construction except for its vertical arrangement, and in this machine the gas filling is usually helium or argon. The journal bearings are of metal, a chromium-plated steel shaft running in cast-iron meehanite bushes, but the stationary member of the thrust-bearing pair is of copper-carbon composition to reduce starting torque and to provide excellent anti-galling properties for starting and stopping. The pump is so designed and positioned in the circuits that it also acts as a surge tank, and the pump bowl contains baffles to prevent undue turbulence of the liquid surface in order to reduce gas entrainment in the liquid metal. A notable feature of this application is that nuclear radiations emitted by the liquid in the pump bowl have no effect upon the gas bearings, whereas organic lubricants deteriorate seriously in radiation fields. In very strong radiation fields it would be necessary to provide extra nuclear radiation shielding for the motor windings, as has indeed been done in later designs, unless radiation-proof windings are developed, insulated, for example, by inorganic materials such as ceramics. The gas bearings may be operated as hot (or as cold) as convenient, provided that the materials are not thereby distorted, thus easing the problem of thermal de-coupling between pump and motor.

The principal disadvantages of this arrangement are that a gas-liquid interface level must be maintained in the region between the pump and motor units and kept as free as possible from surface agitation, and also that the vapour of the pumped liquid has access to the bearings and the motor components. Liquid-filled systems usually require a surge-tank, and it is sometimes practicable to combine this with the pump. Advantages of this type of pump include the avoidance of shaft seal problems or the alternative difficulties of lubricating the bearings with the pumped liquid.

MANUFACTURE

Satisfactory bearings can be made using simple and familiar machining and finishing processes, but care must be taken at appropriate stages in manufacture to ensure that adequate stress-relieving heat treatment is carried out. In the work described, for the journal bearings the final geometrical accuracy and surface finish required is obtained by means of a standard bench honing machine for both shafts and bushes, resulting in roundness to within 0·00005 in., and parallelness within 0·0001 in. (both on diameter), over the entire length of bearings 2 in. in diameter and up to 8 in. in length. Bushes were honed straight from lathe turning, but shafts were usually ground before honing. Given high-quality grinding equipment, as is used for the manufacture of gauges, these bearing components may be readily produced directly from the grinding machine. The honing process gives a surface finish of between 1 and 6 micro-inches, depending upon the material, which is entirely adequate for practical gas-bearing work. The effect of an unduly rough finish is to cause initial rubbing contact at rather high speeds on slowing to rest, and, conversely, an unduly high speed must be attained after first starting before the hydrodynamic gas film is formed. Diameters were measured with pneumatic gauges.

Thrust plates are usually ground and machine-lapped, pumping grooves on grooved plates being ground into the surface on a special

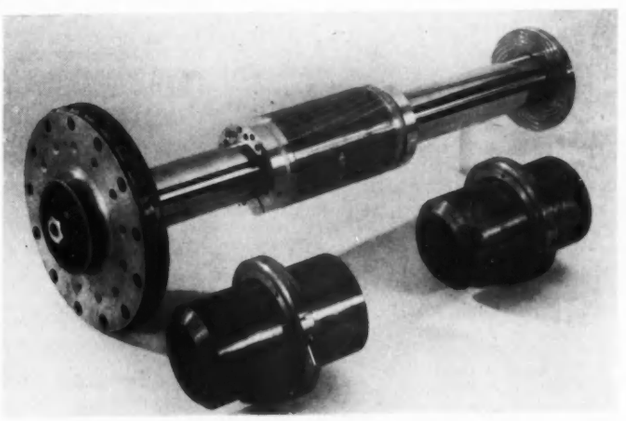

Fig. 8 Rotating components and bearings of carbon dioxide circulator. The bearings shown have electrostatic probes for observing the dynamic behaviour of rotor.

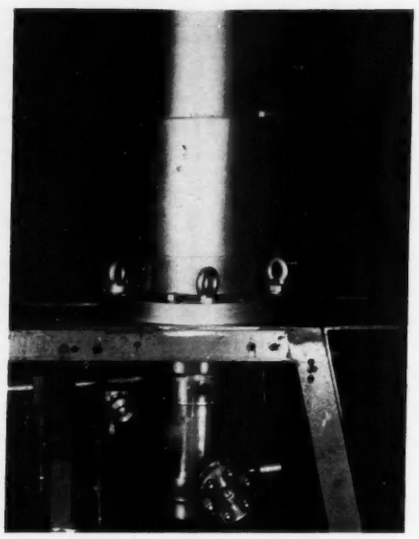

Fig. 9 Pump for molten bismuth. High temperatures and particulate matter in suspension required the use of gas-lubricated bearings. Liquid metals can be used as carrier fluids in a nuclear reactor for uranium or thorium.

machine after lapping. The flatness, readily obtained, is within one or two fringes of sodium light as measured using an optical flat in contact with the plate to be tested.

The self-aligning mountings are arranged to cause the least possible distortion to the bearings. In machines, journal bearings are mounted in thin metal diaphragms the thickness of which is chosen by trial and error as a compromise between being so thin (0·007 in. in the machines described) as to cause bearing flutter, and being too thick (0·030 in.) to allow adequate self-alignment. These diaphragms are usually made from sheet metal by grinding their external and internal diameters when assembled as a firmly-clamped stack in a jig. Care is taken when assembling journal bearings into their diaphragms to ensure that the diaphragm mountings are accurately square to the axis of the bearing, and that the diaphragms are truly flat. A gymbal mounting for the journal bearings has been used for cases in which there is insufficient room for a diaphragm mounting. The stationary member of the thrust bearing is fitted on a gymbal mounting in a holder so as to ensure freedom from distortion, while the rotating member is clamped to the shaft truly square to the axis by a means which guarantees freedom from distortion due to clamping stresses. This can be checked after the shaft and plate have been assembled by means of an optical flat provided with a central hole so that it may be slipped over the shaft. The components are cleaned before assembly in trichlorethylene.

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15,000 TON HYDRAULIC RUBBER FORMING PRESS

New Equipment for Canadian Aircraft Construction

A 15,000 ton hydraulic rubber-pad forming press believed to be the biggest of its kind has been in operation since mid-July at the works of Avro Aircraft, Limited, Malton, Ontario, Canada, forming parts for Avro's prototype CF105 supersonic delta-wing fighter aircraft.

Designed and manufactured by G. Siempelkamp and Company, Ritterstrasse, Krufeld, Rhineland, Germany, to Avro Aircraft requirements, the new press operates at high speed, going through its complete cycle of operation in one minute.

An unusual feature of the press is that the whole pressure is exerted from below, forcing the loading table up into the rubber pad. Another point of interest is the columnless frame construction, the frame being built up in steel " wafers " in groups of six. Each " wafer " weighs 10 tons. About 20 ft. of the press is below floor level and the foundations go down 38 ft.

The 10 ft. by 5 ft. rubber pad, 12 in. thick and weighing 3,686 lb., was specially manufactured by the Goodyear Rubber Company. Some 1,600 gallons of oil are required to operate the hydraulic system, and the electric motors driving the high-pressure hydraulic system total about 600 h.p. The weight of the press is about 600 tons.

The fast advance stroke is made by a 500 ton cylinder in the centre of the press. A big oil tank under a continuous 30 lb. pressure makes possible the high speed. Four pull-back cylinders located on the side of the main cylinder effect the return stroke. A hydraulic equalising device compensates for any eccentric load on the loading table even under the maximum pressure.

Two loading tables, one on each side of the press, are hydraulically operated with high speed and cushion slow-down for both directions. It is the first press which has a hydraulically-operated packing-change device. All important guides and bearings are connected to a pressure greasing system.

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SOLDERLESS TERMINALS FOR ELECTRICAL WORK

The terminals by which connections are made to switches and electrical apparatus of all kinds usually consist essentially of a barrel, into which the conductor is inserted, and a tongue, which is attached by one or other means to the equipment. The design of this tongue depends on the part to which attachment is to be made, the necessity for ready removal or security against looseness and space requirements. A number of designs are available, most of which satisfactorily fulfil these requirements.

On the other hand the design of the barrel is more complex owing to the numerous conditions that have to be fulfilled. These depend on whether solid or stranded wire is used and the number and size of the conductors; on the type of insulation, including that of the barrel itself; and also on such factors as the current carried, mechanical stress, vibration, corrosion, operating temperature and limitations which may be imposed by space.

To secure the conductors in the barrel it has long been customary to use solder. This, however, has the disadvantages of causing risks to the insulation and requiring a certain skill in installation. Crimped cable terminals which, while overcoming these drawbacks, also enable the work to be carried out more quickly have therefore become increasingly popular in recent years and a number of types are now being marketed by Aircraft-Marine Products (Great Britain), Limited 60 Kingly-street, Regent-street, London, W.1.

These terminals consist essentially of a tinned copper barrel, which is crimped on to the conductors by a special tool. Any one of a number of types of crimp are suitable for stranded conductors, since it has been found that the total expansion of the strands is greater than the relaxation of the terminal barrel. After crimping, therefore, the conductor continues to exert pressure against the inner wall of the barrel. On the other hand, solid conductors crimped by conventional means do not expand as much as the terminal barrel when the crimping force is removed and pressure between the conductor and the inner wall of the terminal barrel is lost. For a crimp to be satisfactory for a solid conductor pressure against the barrel must therefore be maintained, and one way of doing this is to form two mechanical toggles by abutting the ends of the folded-over sleeve. This type of crimp, which is also suitable for stranded conductors, exerts increased pressure owing to the elastic expansion which occurs in the sleeve after crimping.

In addition to the standard types of barrel for stranded conductors, Aircraft-Marine Products (Great Britain), Limited, have also designed a pattern which provides support for the conductor insulation and can itself be insulated. In this case the barrel is formed into a closed cylinder and encircled by a thin copper sleeve which prevents the seam from spreading when pressure is applied. To lock the stranded conductor into place the barrel is flattened into an oval shape by a double cross clamp. Insulation is provided by a plastics sleeve which is bonded to the outside of the copper sleeve, the plastics being hardened subsequently to withstand the crimping pressure. Another type of barrel is of open U-shape before crimping and has internal tines which preserve the insulation and make contact with the conductor as crimping takes place. This is obviously only suitable for relatively low currents.

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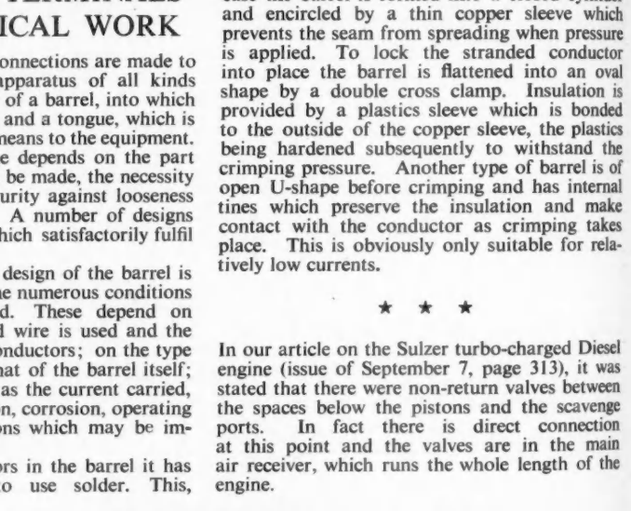
In our article on the Sulzer turbo-charged Diesel engine (issue of September 7, page 313), it was stated that there were non-return valves between the spaces below the pistons and the scavenge ports. In fact there is direct connection at this point and the valves are in the main air receiver, which runs the whole length of the engine.



In the 15,000 ton Siempelkamp hydraulic rubber forming press recently installed at Avro Aircraft Limited, the loading table is forced upward into the 10 ft. by 5 ft. by 12 in. rubber pad. The press is shown here during installation, nearly completed.

CALDER HALL SERVICES RENDERED

Concluded from page 539

This week we conclude our article on the contributions made by contractors and sub-contractors to the building and installation of Calder Hall nuclear power station. In this final part we deal with the preparation and laying of the graphite moderator, reactor monitoring equipment, electrical gear, materials (including structural steelwork, steel plate, tubes, pipes and ducts), and certain miscellaneous items. We have previously covered the history and origins of the station, its construction, the pressure vessels and heat exchangers, the gas circulation and turbine plant, pumps and valves, reactor charging and discharging equipment, and the reactor control and shut-off system. Two other articles on the Calder Hall station have appeared in ENGINEERING: *one, published on October* 5 (*page* 418), *provided a general introduction to the plant, while a second, on October* 12 (*page* 469), *dealt with problems of engineering design. At the end of the present article we give a list of contractors and sub-contractors, with their addresses. We have only been able to describe equipment where information has been made available by the company concerned and passed by the United Kingdom Atomic Energy Authority.*

Reactor Core

We have already described the construction of the reactor core (October 12, page 473), and indicated the way in which the graphite moderator was built up from 58,000 graphite bricks. The Calder Hall reactors are known as thermal reactors since the neutrons which cause the fission of the uranium 235 atoms have been slowed down to thermal speeds in order to increase the probability that this reaction will occur. The moderator serves to achieve this slowing down. The graphite was supplied by *British Acheson Electrodes Limited*, machined by the Authority, and erected by *Matthew Hall and Company, Limited*. A workman is seen tapping graphite blocks into position in Fig. 32. The moderator is provided with channels in which the fuel elements and control rods are inserted. The operation of the control rods was described last week and the general features of the fuel elements in our issue of October 12 (pages 472 and 473). Although the Atomic Energy Authority were generally responsible for the fuel elements, the difficult task of machining the fuel element cans was carried out by the *Fairey Aviation Company, Limited*. It has recently been released that the weight of uranium fuel per reactor is of the order of 120 tons. This is probably not distributed evenly throughout the reactor, but arranged to achieve "flattening" of the neutron flux across the core and consequently an even heat distribution. The pitch of the fuel elements is 8 in. and there is one hole in the pressure vessel per 16 fuel channels; the charging equipment is designed accordingly.

The correct operation and safety of a reactor entails continuous monitoring for faults and dangerous levels of radiation. Among the most serious faults is the fracture of a fuel can due to the distortion of a fuel element under irradiation and thermal stress; and to give warning should this occur, precipitator units are employed. A battery of these for monitoring reactor No. 1 is shown in Fig. 33. The basic principle of detection involves taking a small sample of the coolant gas from each of the uranium channels in turn, and monitoring this sample for radioactive components. If the reactor is free from radioactive contamination then the sample of gas will not contain any radioactive particles, but as soon as a pinhole appears in a uranium fuel element then fission products can escape, and if the pinhole develops, uranium oxide may also become entrained. In order to prevent this circulating to the rest of the detection system, the gas is first filtered. Some of the fission products are in gaseous form and these will pass through the filter. A proportion of these gaseous fission products have quite short half lives so they soon decay, forming solid particles which can be deposited on a thin wire by electrostatic precipitation. The wire is moved from the precipitation chamber and monitored by a counter. The count is representative of the size of the burst, and is obtained in such a way that the measurement has been segregated from the normal high-intensity radiation which is present in and around the reactor core.

Fig. 32 Workman tapping graphite blocks into position during the construction of the reactor core. The graphite moderator contains channels in which fuel elements and control rods are inserted. It has been stated that the uranium charge per reactor is approximately 120 tons.

The burst slug detection gear has been designed by *Plessey Nucleonics Limited*, one of The Plessey group of companies, in collaboration with the U.K.A.E.A., to provide automatic warning of excessive radioactivity caused by faulty fuel cans. Failure to detect faulty fuel elements would result in the release of fission products, which would spread radioactivity through the entire gas circuit. As has been stated, detection is effected by examining small samples of the coolant gas circulating around the fuel cans. Each of the Calder Hall piles is divided into eight separate areas, each controlled by a 54-point gas-sampling plant which transmits signals back to a central control room. From each of these areas, 212 gas-sampling pipelines are led through manually operated cocks, which reduce the number of channels to 53 by combining them in groups of four. Each of the 53 pipelines is connected to the inlet ports of a 54-way selector valve, which in turn links them to outlet ports. Samples of the gas are taken from each inlet port every 27 minutes, with the valve remaining stationary at each inlet for 28 seconds and taking two seconds to travel between ports. The 54-way selector valve of each area is connected by single pipeline, by way of a cooler and filter, to its own precipitator unit.

When a fuel container is damaged, fission products, some of them in gaseous form, escape into the main coolant stream. The particles are arrested by the filter, but some of the radioactive gases pass into the precipitator unit where they decay and become deposited, by electrostatic precipitation, on a wire which remains stationary for 28 seconds during the sampling period. The front of a precipitator unit is illustrated in Fig. 34 and the rear in Fig. 35. At the end of this period, the portion of wire carrying the radioactive deposit travels for two seconds to a scintillation counter, remaining there another 28 seconds for checking. The scintillation counter operates a rate-meter which in turn indicates on a 54-way recorder in the control room, and if a high radioactive count is registered a warning bell rings. During the time that the section of wire is being checked for radioactivity, a gas sample is taken from the next inlet port on the selector valve and the products are deposited on another portion of the wire. No part of the wire is used more than once in 30 minutes, thus allowing long-lived activity to decay.

Overall sampling of the gas coolant in the pile is governed by a 9-point gas-sampling plant comprising 8 additional pipelines (4 from the inlet and 4 from the outlet gas ducts) joined to the 8 inlet ports of a 9-way selector valve. Each inlet port is connected in turn with an outlet port and the valve remains stationary for a 28-second sampling period at each inlet and also takes two seconds to travel between ports. Each inlet is checked, therefore, once every 4½ minutes. This 9-way selector valve is connected, by way of cooler and filter by a single pipeline to a duct precipitator unit, similar in operation to the others. Any suspect pipeline can be sampled continuously by diverting it to one of two spare precipitator units, which, operating in conjunction with a single-point recorder in the control room, constitutes a single-point gas sampling plant.

The 54-way selector valve consists of a body with 53 inlet ports, the 54th position having an internal transfer port which maintains gas flow through the valve. Each inlet port is connected in turn with an outlet port by the operation of a rotor arm. This is coupled to a worm housing driven through a free-wheel mechanism by a motor fitted with an electro-magnetic brake. As the rotor arm approaches an inlet port, a cam mechanism fitted to the housing snaps it forward into position, and the free-wheel mechanism is disengaged by the drive motor. The circuit to the valve motor is, at the same time, broken by a valve switch.

A 54-way selector switch, which is driven from the worm housing, contains a "synchro," together with a 6 and 9-way switch. The synchro operates the repeater of a 54-way dial indicator, which is located in the control room and provides remote indication of the valve rotor-arm position. The 6-way switch operates 54 times successively during the 9-way switch cycle. There are nine pens located in the recorder carriage, each of which is governed by the 9-way switch. Each carriage position is registered by neon indicators situated on the recording dial, and the 6-way switch controls the movement of the 54-point recorder carriage.

The precipitator unit comprises a cylindrical casting fitted to a stand which houses a control chassis, H.T. unit, ratemeter and indicator panel. The casting contains a precipitation chamber, assembly and a scintillation counter; a precipitation wire passes through these and round driving and idling end pulleys to form a continuous loop. The casting also shields the counting equipment and provides a pressure seal for the system. For convenient servicing, the casting is supported on a welded steel framework such that the axis of the casting is approximately at eye level. The control circuit for the wire-motor and valve-motor is housed in the control chassis and failures within the gas sampling plant are visually indicated by warning circuits. Faults registered include failure of the H.T. supply unit, failure of the gas flow, excessive rise in the gas temperature, failure of drive motors, leakage of gas through the drive seal and breakage of the pulley wire. The H.T. unit provides the high positive potential on the precipitation chamber outer electrode relative to the wire, and the rate meter is operated by the output from the scintillation counter. A gas-temperature gauge, which operates a warning circuit, and a gas-pressure gauge are contained in the indicator panel.

The system on which the plant operates may be gathered from the circuit in Fig. 36. The gas enters the precipitation chamber maintained at 5 kV, which creates an intense electric field between the outer electrode and the precipitator wire held at earth potential. Radioactive atoms of gas which decay into a solid state are deposited on the precipitator wire. At the end of the 28-second sampling period, this portion of the wire is moved to the scintillation counter, and the selector valve moves to the next inlet port. The radioactive solids deposited on the precipitator wire decay again by emitting beta particles (electrons) which pass through a phosphor cylinder mounted concentric with the wire. Light flashes produced during this decay are detected by a photo-multiplier which is in contact with the phosphor in the cooling tube. The ratemeter sums up or integrates the number of light flashes over the measuring period of 28 seconds and this is shown on the recorder in the control room. Control and warning circuits for each plant are completed through a switchboard and any faults developing are visually indicated on the switchboard and by group warning alarms in the control room. In addition, high counts of radioactivity detected in any plant also operate warning alarms. In the event of a serious fault occurring in a precipitator unit, one of the two spare precipitators is brought into action. This is effected by means of a switchboard.

The presentation of the sampling results involves a considerable volume of data which must be presented to the plant operators in such a fashion that when a fuel element fault arises, it may be rapidly located without the operators having to sift through a mass of data. The method adopted makes use of a specially modified recorder. This will be described in further detail below. Each recorder is arranged so that 54 separate small charts are obtained, each about 1·5 in. square. This is achieved by having 9 vertical pens attached to the recorder which can be zeroed into 6 columns. The chart speed is arranged to move 1·5 in. in 24 hours, thus giving 54 small pictures of the activity in a conveniently small space. The record in each small chart takes the form of a series of dots the horizontal distance of which from the column zero is proportional to the activity count. When a flaw arises in any one channel, the record will be seen to move rapidly to the right and may be readily identified. In many cases the onset of a flaw may require additional attention. Provision is therefore made for a standard full-scale recorder to be switched in, and this enables a more detailed study to be effected.

Severe flaws will result in a very high reading being obtained from the counter, and a device is incorporated such that when the count exceeds a pre-determined level, a warning bell is operated in the control room. This ensures that operators will have their attention immediately drawn in cases of emergency, while the overall system enables a mass of data to be handled conveniently.

The 54-point scanning recorder is the model ND 51 made by *Elliott Brothers (London) Limited* and illustrated in Fig. 37. Eight of these are installed in the reactor control room. Basically, the instrument is an Elliott self-balancing potentiometer recorder, but the following modifications have been made. Additional gearing has been provided to enable chart speeds as low as 1 in. in twenty-four hours to be achieved, and special precautions have been taken to avoid "snatching" and irregular chart movement at minimum speed. Secondly, normal chart paper has been replaced by the Teledeltos electro-sensitive type. The use of Teledeltos recording paper makes it possible to provide alarm facilities indicating any failure to print a given input. When this facility is combined with the abnormal-value alarm, a plant operator can safely rely on the recording installation to give a quick indication of plant or recorder abnormalities. A further optional facility allows the operator to record one selected variable only for a period which enables him to judge quickly whether an abnormal condition is transient or permanent and therefore requiring action on his part. Another modification is that one arm of the resistance bridge network has been provided with six tapping points. This enables six separate zero balance points to be obtained equi-spaced across the chart. In this way the chart is divided into six spans in each of which values of the input variables may be recorded. In place of a single pen, the moving carriage has been equipped with a pen bar carrying nine tungsten pens equally spaced vertically down the chart. The pens are normally held a short distance from the paper and can be separately

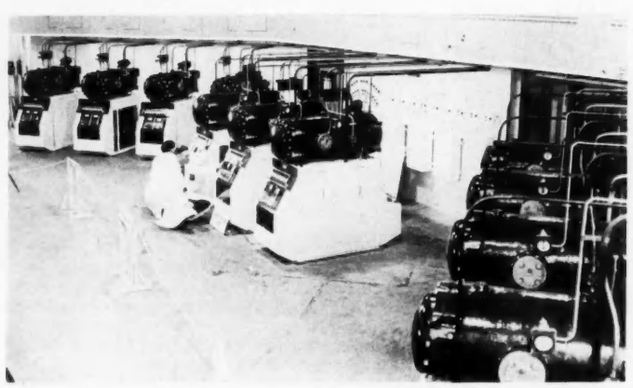


Fig. 33 Battery of precipitator units for detecting burst fuel slugs in reactor No. 1. Distortion of a fuel element under thermal stress and irradiation might cause the fracture of the protecting can.

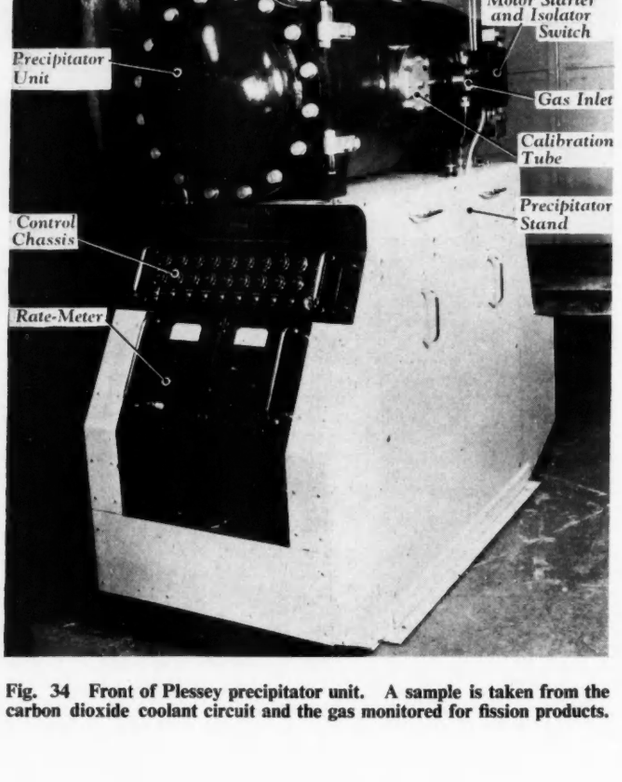


Fig. 34 Front of Plessey precipitator unit. A sample is taken from the carbon dioxide coolant circuit and the gas monitored for fission products.

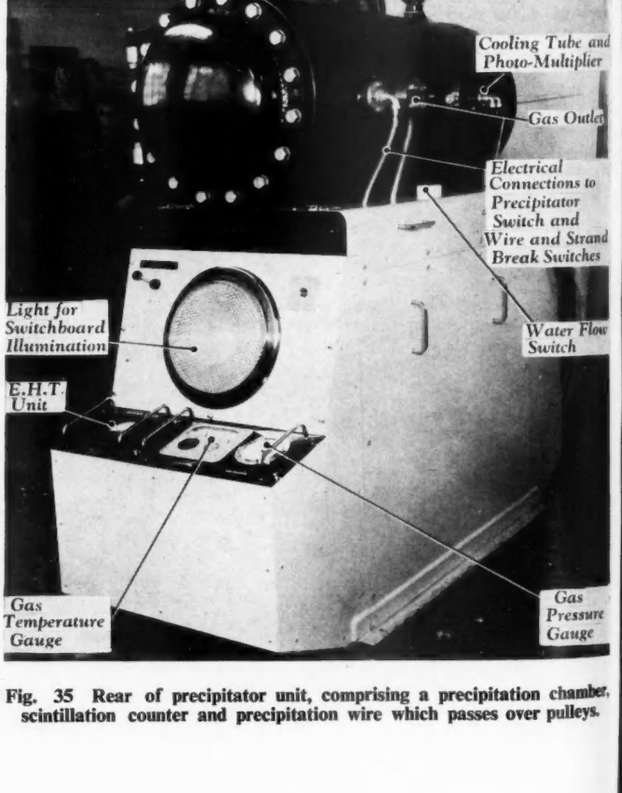

Cooling Tube and Photo-Multiplier
Gas Outlet
Electrical Connections to Precipitator Switch and Wire and Strand Break Switches
Light for Switchboard Illumination
Water Flow Switch
E.H.T. Unit
Gas Temperature Gauge
Gas Pressure Gauge

Fig. 35 Rear of precipitator unit, comprising a precipitation chamber, scintillation counter and precipitation wire which passes over pulleys.

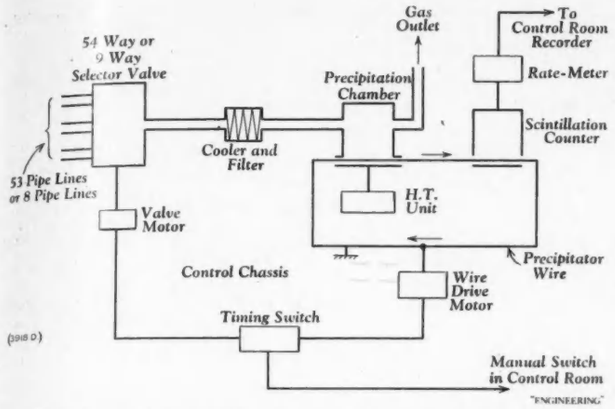


Fig. 36 Circuit for precipitator system. After a sample of coolant has been taken, any gaseous fission products that may be present pass to a precipitator unit, where some decay and are deposited by electrostatic precipitation on a wire. This passes to a scintillation counter which measures the activity.

connected to a charged capacitor via sliders on nine bus-bars. A solenoid-operated bar causes all pens to be pressed on the paper and the bus-bar connections enable one selected pen only to be fired and so record on the paper. The combination of six spans and nine pens provides a recording facilitity for up to 54 inputs. The complete equipment for multipoint recording comprises the scanning recorder together with an external scanning unit. This utilises a Uniselector type of stepping switch and a motor-driven cam which programmes the data sampling and printing sequence.

Elliott Brothers have also provided a variety of items connected with the remote indication of steam and oil pressure and flow, vacuum, temperature and carbon dioxide circulation. This equipment includes some 40 Drimac force-balance transmitters, one of which is illustrated in Fig. 38. A part-section view of the unit appears in Fig. 39. The Drimac transmitter is suitable for the measurement of liquid or gas flow, liquid level, and pressure; its application to the measurement of liquid level is shown on the left of Fig. 40 and on the right to the measurement of liquid flow. The instrument serves to balance automatically the force developed by the condition to be measured against a pneumatic pressure, which is a convenient medium for transmission to remote recording and controlling units. The operation is as follows: the force to be measured is applied to one end of a pivoted beam, the other end of which acts as a throttle, controlling the passage through a nozzle of compressed air supplied via a restriction. The air supply is also connected to a balancing diaphragm, arranged to exert on the beam a balancing force dependent on the amount of restriction at the nozzle.

Not only must the reactor be monitored for burst fuel slugs but also for gamma radiation. For this purpose *Isotope Developments Limited* have supplied their reactor gamma monitor type 1457A. It is a mains operated instrument with a logarithmic scale designed to measure the level of gamma radiation in the vicinity of the reactor. It consists of two main units, a head amplifier with ionisation chamber, and a direct-current amplifier with a high level alarm. The instrument covers the range of 0·01 to 10^3 Röntgens per hour, and the alarm system is adjustable over the whole range. The ionisation chamber is constructed entirely of material of low atomic number and has an equivalent air-wall so that dose-rate readings are energy-independent over a wide range of gamma-ray energies. The instrument conforms to the specification RCS. 1000.

Reactor Control Panels

The control of the Calder Hall "A" station is effected broadly through two sets of control equipment. One set is concerned with the reactors the other with the generation and transmission of electricity. The reactor controls are actually located in two rooms, one per reactor. There are also other sets of controls—in the coolant blower room for example—but generally control is centralised. The electrical control gear and associated equipment will be dealt with later.

The reactor control rooms of the "A" station were built by *New Western (Engineering) Limited*. The instrumentation required was largely designed or specified by the U.K.A.E.A., but use was made of various instruments manufactured by *George Kent Limited*, whose Multelec recorders are employed for the measurement and control of radioactivity, reactor power level and temperature; a number of Kent flow recorders and draught gauges are also installed. Fig. 41 shows part of the reactor control room; another view appeared on page 421 in our issue of October 5, and on page 474 (October 12) we illustrated a display panel corresponding to the plan of No. 1 reactor and indicating the position of the control rods.

New Western, in addition to the provision of the panel, desk and other control room furniture, carried out all instrument erection, both in the control room and on the site, together with the necessary wiring and pipework. They were also entrusted with the testing and commissioning prior to the handing over of the plant to the operating staff. An interesting aspect is the use of New Western non-reflecting finish on the panels. This completely eliminates all reflections, yet does not suffer from the dead appearance usually associated with matt finishes. The all-over ceiling lighting, together with the colour reflectivity of the floor, was taken into consideration when the mimic diagram line colours were chosen. The result of this can be seen in the illustration. Contracts for a further six similar control rooms for Calder Hall "B" and the Chapel Cross station have been placed with the same company.

Electrical

The electrical plant at Calder Hall is necessarily similar to that employed in conventional power stations, but is interesting in that it shows how a nuclear power station can fit into an established grid system. The efficiency of the station, heat to electricity, is said to be a little over 20 per cent., with some 20 per cent. of the total generated capacity fed back to supply auxiliaries. Part of the output will serve to supply the power which the Windscale plant formerly drew from the grid; the remainder of the 184 MW output of the "A" and "B" stations (some 150 MW) will be available to the C.E.A. The generating plant, which has been supplied by *C. A. Parsons and Company, Limited*, was described on page 534 in our issue of October 26. The 11 kV generator switchgear with associated control and ancillary equipment was supplied by *A. Reyrolle and Company Limited*. The main power control room for Calder Hall "A" is shown in Fig. 42, on page 567.

The switchgear, which is of the metal-clad horizontal-drawout type, with oil-break circuit breakers, is installed in two switch houses. One of these is situated in the power station at Calder Hall and houses two 500 MVA switchboards, each comprising three Reyrolle type B5T circuit-breaker panels. The other is situated some 1,000 yards from the power station in a sub-station at Windscale and houses a 750 MVA switchboard comprising seven Reyrolle type A3T circuit-breaker panels which are divided into two 3 panel sections. Each of the 500 MVA switchboards and each section of the 750 MVA switchboard controls a 30 MVA transformer connected to the Central Electricity Authority 132 kV grid, a 23 MW generator, and an outgoing feeder to a nuclear pile through a 30 MVA reactor. The four generators are all housed in the power-station turbine hall, and controls for all of these and also tap-change facilities for all four grid transformers are available from the main control room at Calder Hall. There is also a local control board at Windscale for all the switchgear at this substation.

The power-station main control board is of the corridor type, with instruments, controls, and a superimposed line diagram on the front panels, and with the relay cubicles at the rear. This board accommodates the control, instrumentation, and A.V.R. equipment for all four generators, two on standard controls, and two on a 50 V direct-current direct-wire "miniaturised" control. The standard controls for the Calder Hall reactor feeders and grid-transformer feeders, are also included on this control board together with 50 V direct-current miniaturised tap-change controls for the grid-transformer feeders at Windscale. Each circuit is equipped with a 50 V direct-current alarm facia and associated relay equipment. A general-purpose cubicle is situated in the centre of the control suite, to house the general-purpose alarms and the normal and emergency lighting changeover facilities. There are two synchronising cubicles with miniaturised equipment situated one at each end of the control board,

Fig. 37 Sampling results from the precipitator system involve numerous data and to present them as simply as possible an Elliott 54-point scanning recorder is employed.

either of which may be used for synchronising the generator or grid-transformer circuits. The control-room engineer's desk is of light oak, with metal inserts accommodating the controls for the four generators and the tap-change equipment for the four grid transformers, duplicated from the main control board. The desk has the usual facilities of drawer space, writing desk, and G.P.O. and operational telephones.

The control board at Windscale is also of the corridor type with normal synchronising facilities, and is for the control of the 750 MVA switchgear at this substation, which is normally unmanned. For centralisation of the main controls, however, the two generator panels at this station and the tap-change equipment for the two grid transformers connected to it are normally controlled over the 50 V miniaturised system from the main control board at Calder Hall already referred to above. Two cubicles are incorporated at the rear of both the power station and the sub-station control boards to house the relays associated with the bus-bar-zone protection of the metal-clad switchboards. The protection is

a high-impedance system operating on a differential current-balance principle, and is arranged to give both phase-fault and earth-fault protection.

Reyrolle moreover installed the 1,500 A main and the 60 A generator drain resistors, and also the single-phase type-ASPT metal-clad switchgear with oil-break circuit-breakers for neutral earthing, together with the associated generator-pit copper work and case-type current transformers for metering and protective services. They were also responsible for the installation of the associated multicore control cables and the 240 V, 110 V and 50 V battery equipment the *Tudor Accumulator Company, Limited.*

Auxiliary switchgear has been supplied by the *English Electric Company, Limited*, who will also make the corresponding equipment for the Calder Hall " B " station and for the station at Chapel Cross. The auxiliary switchgear for these stations is of air-break type and is at two voltage levels, namely 415 V and 3,300 V.

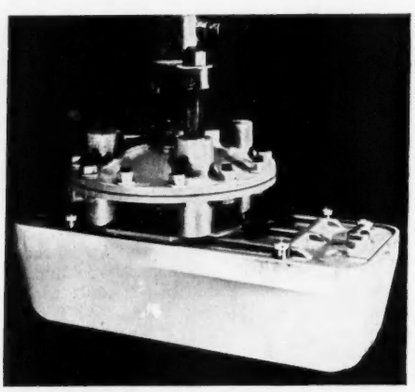


Fig. 38 Elliott Drimac force-balance transmitters are used at Calder Hall for the remote indication of steam and oil pressure and flow, vacuum, temperature and coolant circulation.

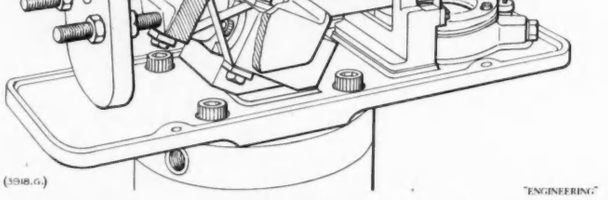


Fig. 39 Cut-away view of Drimac transmitter. The force developed by the condition to be measured is balanced against a pneumatic pressure.

The 415 V switchgear has a maximum current rating of 1,600 A and is of English Electric type OB3, as shown in Fig. 43, while the 3,300 V switchgear type OB33L has a maximum current rating of 800 A with a 150 MVA fault rating.

For the turbine hall and the four generators at Calder Hall " A," two 3,300 V switchboards of 14 and 15 panels respectively, and two 8 panel 415 V switchboards have been provided. Also there is a 13 panel 3,300 V switchboard controlling the five circulating water pumps in the pump house. For the reactors, two 13 panel 415 V switchboards are installed, one to each reactor house, and these feed, among other circuits, the control-rod generator sets for the reactor controls.

Switchgear associated with the Calder Hall "A" station is controlled from a central point by means of a system of direct wire control, designed and manufactured by the Power Signalling Division of the *Automatic Telephone and Electric Company, Limited.* Among other functions, it provides indication of alarm conditions, remote instrument readings, and the control and indication of the main transformer tappings for voltage variations. The system has to operate equipment scattered over distances of more than 1,000 yards, and over two miles of multicore cable were used in local wiring alone. The same company has also made some of the switchboards for the main control room, and will be supplying similar equipment for Calder Hall " B." Certain transformers have been made by the *Bryce Electric Construction Company, Limited.*

British Insulated Callender's Cables Limited received their first contract in September, 1954, for the installation of power, telephone and control cables and large quantities of ancillary equipment. They have also undertaken a corresponding contract for Calder Hall " B," which calls for over 10½ miles of 11 kV cable, 4,000 yards of control cables, 800 yards of telephone cables, and ancillary equipment. The installation work was carried out by *British Insulated Callender's Construction Company, Limited.*

The major part of the work involved the laying of 11 kV cables carrying the output of the station's four 28·75 MVA rated turbo-alternators. Two of these are connected by 11 kV single-core cables laid in trefoil formation to two 500 MVA switchboards and thence to two C.E.A. 30 MVA transformers at the new Calder Hall transformer station, a total cable run of 240 yards. Similar cables connect these two switchboards via reactors to 350 MVA switchboards, housed in each of the reactor buildings and, from them, supply the thermal (nuclear) reactors with power for their gas pumps and auxiliaries. The 350 MVA switchboards are interconnected by a 250 yard run of this cable. The output from the other two turbo-alternators is fed by eighteen 11 kV single-core cables laid in six trefoil groups to a 750 MVA switchboard located in a new switch house near Windscale Works. From this switchgear, 11 kV cables connect to two transformers at the C.E.A. Windscale transforming station. This main cable route, 1,100 yards long, between Calder Hall and Windscale is also shared by 18 multicore cables used for control circuits. The cables, 36 in all, were laid in a trench, 15 ft. wide and 3 ft. 6 in. deep, for most of their length. Where the route crosses the River Calder, however, the cables are carried over the river by a steel bridge, 250 ft. long, built specifically for this purpose. Fig. 44 is a view of the cable basement of the turbine house, showing three cable tunnels. The right-hand cable tunnel takes two sets of 11 kV cables from switchgear in the turbine house to two 11/132 kV transformers in the C.E.A. compound at Calder Hall. These cables (9 by 11 kV single-core per transformer) are on the right and centre of the picture, rising from concrete slabbed brick chases. The 11 kV cables on the left are for generator No. 2 and run to Windscale down the left-hand tunnel. The 11 kV cables crossing the centre tunnel (9 by 11 kV) run from the electrical reactor down the tunnel to the thermal-reactor switchgear. All multicore cables in the illustration are associated with these 11 kV cables.

Originally, Windscale Works derived its power from the National Grid; the B.I.C.C. group had previously constructed the 132kV line from Roosecote Power Station, near Barrow, and supplied and installed 600 yards of 132 kV gas-filled single-core cable for the termination of two of the overhead line circuits at the Windscale Transforming Station. Now, it will be able to use power from Calder Hall, so the B.I.C.C. contract included cutting the original 11 kV feeders from the transforming station to the works and re-routing them via two reactors into the new 750 MVA switch house. The power circuits described above use three 11 kV 1·0 sq. in. conductor, paper-insulated, lead-alloy sheathed and served single-core cables per phase, and were cleated using non-magnetic cleats of special design. Three types of cleats were used: single, trefoil and, for use on vertical runs, independent trefoil. Horizontal runs of cable were cleated at intervals of 6 ft. 6 in. This spacing is rather wider than the usual practice but was found by B.I.C.C. to be the optimum spacing for use at the Capenhurst atomic energy plant, and it has now been adopted as standard by the U.K.A.E.A. The cables from the alternator are terminated by right-angle sealing ends fixed to the wall of each alternator terminal cubicle.

The control circuits which were installed by B.I.C.C. used multi-cored, paper-insulated, lead or lead-alloy sheathed, wire-armoured and served types of cables. Those provided were 15 pair and 75 pair 20 lb. per mile conductor telephone cables and 4, 7, 14 19 and 37 core 7/·029 conductor cables. For these circuits, numerous distribution boxes and fittings were supplied and installed, including 900, 600 and 360 way " marshalling kiosks " which were specially designed for this installation.

B.I.C.C., in conjunction with *Strachan and Henshaw, Limited*, have developed two new types of cable for use on thermal reactor charging and discharging machinery. These cables are capable of withstanding the high temperatures and radiation encountered by the grabs used to handle the reactor fuel rods without failure or loss of electrical performance. The first type, of which over 40 lengths are being supplied, contains six 19/·0076 nickel-plated copper PTFE insulated cores laid around a central 110 ton quality steel strand and is used at Calder Hall for the electrical control of the reactor charging and discharging grabs. The second type, which is being installed experimentally at Calder Hall, incorporates a flexible central duct in addition to the electric wires, and enables electro-pneumatic control to be achieved with the use of only one flexible cable.

In all, since September, 1954, the B.I.C.C. Group has supplied and installed nearly 17½ miles of 11 kV cable, 7 miles of multi-core control cables, 4 miles of multi-core telephone cables, over a hundred terminal boxes and marshalling kiosks

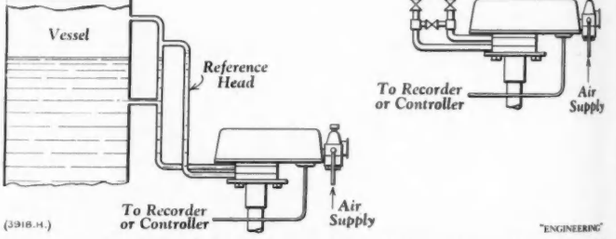


Fig. 40 Application of Drimac transmitter to the measurement of liquid level (left) and liquid flow (right).

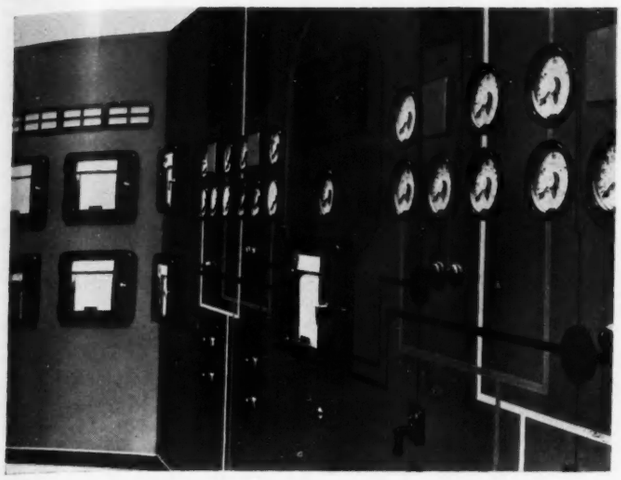


Fig. 41 Part of the control room for No. 1 reactor showing mimic diagrams. Built by New Western, the control room includes instruments made by George Kent Limited.

and large quantities of ancillary equipment, from cable-clamps to capacitors.

Electrical installation work has also been carried out at the Calder Hall "A" station by *N. G. Bailey and Company, Limited*, and their first contract was that for temporary electrical services for all trades throughout the site, together with a distribution network covering the whole site, consisting of P.I.L.C. cables laid underground from site substations, through feeder pillars, to the sites of the several buildings, and also to such specialised sites as that for cement batching. A comprehensive street lighting system was also installed, together with temporary flood-lighting, to enable work to proceed during the hours of darkness. Following the completion of this original contract, the company have carried out the installation of lighting, heating and small-power services throughout all the buildings on the site, including the administration block, turbine hall, two reactors, substations and other items. In addition, they have been responsible for the installation of thermocouples throughout, including associated wiring, installation of compensating cables and final connection. The company have also been largely concerned with the installation of the control and instrumentation cables, including the provision of supporting steelwork, and the very extensive earthing and bonding associated with this system.

N. G. Bailey and Company are also carrying out the whole of the lighting, heating, low power cable work as well as the whole of the control and instrumentation wiring at Calder "B" Power Station.

The British Thomson-Houston Company, Limited has installed two sets of rectifier equipment for supplying the direct-current fan motors associated with the reactor cooling system. Each set comprises two pumpless steel-tank mercury rectifiers and one rectifier transformer with 33 position on-load tap-change gear. The ratings of both items is 233/400/566 kW, 200/240/335 V, 1667/1667/1667A, 2 wire direct-current, 6 phase, and they operate from a 415 V 3 phase 50 cycle supply. This equipment has been made to the specification of *Whipp and Bourne Limited*. B.T.H. have also received an order for two further sets of rectifier equipment for the Calder Hall "B" station.

The safety of the nuclear reactors depends on the continued operation of associated plant in an emergency. To supply power for such an event two large batteries have been installed. These have been provided by *Chloride Batteries Limited*. Each consists of 120 OFW. 13 chloride Plante cells with a capacity of 1,950 Ah at the 10 hour rate of discharge assembled in lead-lined wood boxes. The batteries are each connected in parallel with a twin-bulb 400 kW mercury-arc rectifier set at 270 V. Under normal conditions this provides a floating trickle charge across the 120 cells—2·25 volts per cell. The pumps, fans, instrumentation and emergency lighting for each reactor are normally supplied by the rectifiers, but should their output fail, the batteries automatically take over the load. Absolute reliability of the batteries is essential, for a complete failure of these services could cause severe damage to the reactors. Each battery is capable of supplying 1,200 A for half an hour. Following an emergency discharge, the rectifier is capable of rapidly charging its battery and supplying the reactor's auxiliary services at the same time.

Fans and Blowers

The main blowers for the coolant circuit, which were made by C. A. Parsons and Company, have already been described, but the operation of the station involves a number of other cooling problems. The pressure vessels surface and the reactors' thermal shields, for example, have to be cooled, and this is carried out by means of induced-draught fans. Eight fans of this kind have been supplied by *James Howden and Company, Limited*. These have aerofoil-type blades and are designed to deliver 33,300 cub. ft. per minute against a pressure of 13·3 in. water gauge. Each fan has a V-rope drive from a 120 h.p. motor.

Pipes, Tubes and Ducts

Some impression of the immense quantity of piping required for the Calder Hall station is given by Fig. 45, which shows the complex layout in the basement of the turbine hall. Several companies have taken part in this work both for manufacture and erection. We shall consider in this section not only steam and water piping but also the ducting which carries the reactor coolant gas.

As sub-contractors to *C. A. Parsons and Company, Limited*, who were responsible both for the turbine installation and for the coolant circulating system, *Robert Jenkins and Company, Limited*, have supplied 300 tons of mild-steel fabricated ductwork 4 ft. 6 in. in bore and approximately 1,500 ft. in length for the Calder Hall "A" plant. The ducting conveys the hot gases from the reactor to the heat exchangers and thence through the circulators back to the reactor. It is $\frac{3}{8}$ in. thick and fabricated to full Lloyds Class I requirments. Internal cascade vanes were fitted at bends and the interior shot-blast cleaned and a protective coating applied on completion.

A major contribution of non-ferrous metals for the condensing plant has been made by *Imperial Chemical Industries, Limited*, who have supplied, in addition to 104 tons of condenser tubes, all the plates (134 tons) for the main and dump condensers.

Pipework for the steam turbine plant has been supplied and erected by *Aiton and Company, Limited*. The high and low pressure steam mains from the heat-exchanger superheater outlets to the steam receivers; from the receivers to the turbine steam chest inlet flanges; and to the steam dumping valve inlet flanges are of carbon steel and mainly of tube 16 in. outside diameter by $\frac{3}{8}$ in. thick, with intermediate joints butt-welded by the metal-arc process. These butt welds were examined by gamma radiograph. At terminal points the Aiton "Corwel" seal weld joint has been used. From the outlet flanges of the steam dumping valves to the dump condensers the piping is fabricated from mild-steel plate; bellows expansion joints constructed from $\frac{1}{16}$ in. thick stainless-steel plate are fitted to take the thermal expansion. High-pressure feed piping from the discharge flanges of the feed pumps to the terminal flanges at the heat exchangers is also of carbon steel tube and again the joints are butt welded and gamma-radiographed. There is an extensive system of low-pressure condensate piping, auxiliary steam, station heating, carbon dioxide and high and low pressure piping, all of which has been supplied and erected by Aiton and Company.

Stewarts and Lloyds, Limited, will have supplied over 265 miles of electric resistance weld steel tubes to the main contractor, *Babcock and Wilcox Limited*, for the heat exchangers. These E.R.W. boiler, superheater and economiser tubes are in sizes 2 in. outside diameter by 7 w.g., 2 in. outside diameter by 6 w.g. and $1\frac{1}{2}$ in. outside diameter by 8 w.g., and in accordance with B.S.1654(1950). The main cooling water pipes between the turbine and dump condensers and the cooling towers were also supplied and erected by Stewarts and Lloyds. The pipes were of mild steel to B.S.534, manufactured by the hydraulic lapweld process, the main runs being 61 in. outside diameter by $\frac{1}{2}$ in. thick, the pipes inside the turbine house and pump house reducing to 55 in. outside diameter by $\frac{7}{16}$ in. thick, 39 in. outside diameter by $\frac{3}{8}$ in. thick and $36\frac{3}{4}$ in. outside diameter by $\frac{7}{16}$ in. thick. All pipes were shop fabricated and the intermediate joints were of the sleeve type for internal welding; this work was carried out on site by Stewarts and Lloyds, using the electric arc process. The same company also supplied steel pipes for water services, in sizes ranging from $3\frac{1}{2}$ in. to 16 in. outside diameter. For the mains below ground the Viking Johnson coupling was normally used and for those above ground flanges in accordance with B.S.10 Table E were adopted. The pipes were descaled, phosphate treated and protected internally with bitumen. The external protection for the buried sections

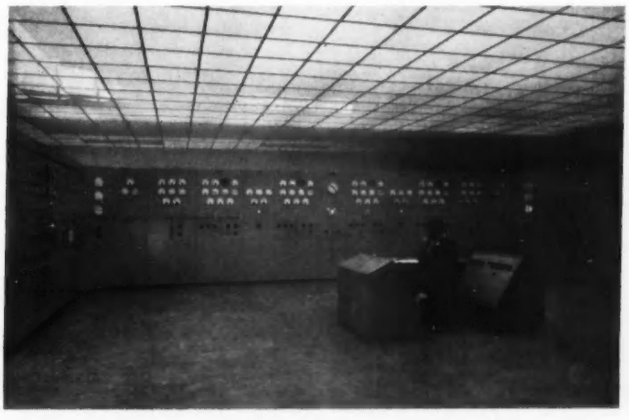


Fig. 42 The main control room at the Calder Hall "A" station is equipped with Reyrolle corridor-type control boards.

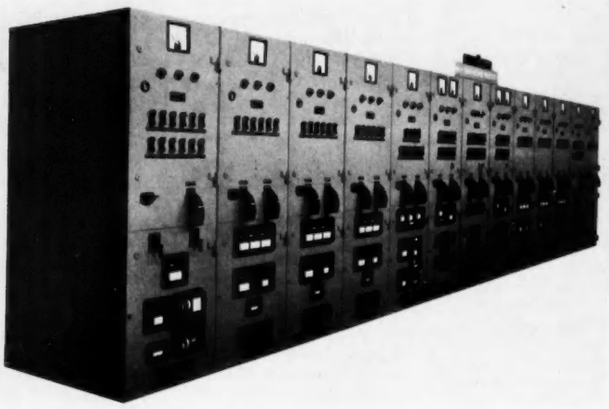


Fig. 43 The auxiliary switchgear is of air-break type and is at two voltage levels, 415 V and 3,300 V. The 415 V switchgear has a maximum current rating of 1,600 A and employs an English Electric 13 panel switchboard.

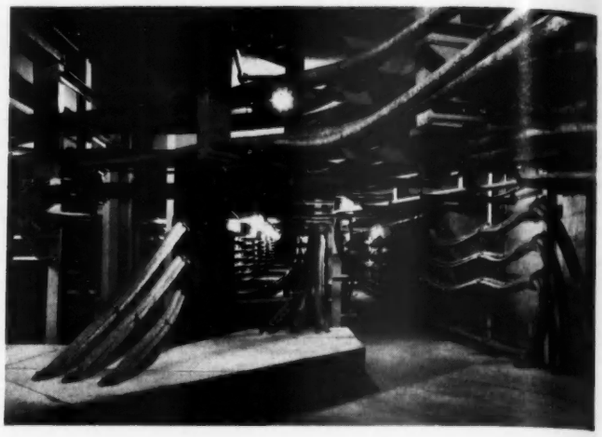


Fig. 44 Cable basement of the turbine house, showing three cable tunnels. The right-hand tunnel takes two sets 11 kV cables from switchgear in the turbine house to two C.E.A. transformers.

was bitumen asbestos sheathing and the pipes above ground were coated with bituminous solution. In addition, Stewarts and Lloyds have supplied to contractors, large quantities of steel tubes for various other purposes at Calder Hall.

Various members of *Tube Investments, Limited*, have provided tubing for the Calder Hall station. In addition to conventional seamless steel tubes, Bourdon and capillary tubing for instrumentation, *Accles and Pollock, Limited*, have produced a number of novel items of special application to atomic-energy work. Their work in this field —though not necessarily applied to the Calder Hall project—includes the development of tubing with wall thickness as low as 0·003 in. to minimise the absorption of neutrons by stainless steel, and finned tube in which the fins are rolled from the tube wall. Flexible tubing in seamless stainless steel and bellows couplings also in stainless steel are other items of special use for atomic-energy applications. Tubular coils in various metals and composite tubing, such as, mild steel lined with stainless steel or copper have also been produced by this company. Accles and Pollock have also produced tubes in such materials as niobium, vanadium, molybdenum, tantalum, titanium, zirconium and beryllium.

Another T.I. company, the *Chesterfield Tube Company, Limited*, have supplied for Calder Hall hot drawn seamless steel tubes 10¼ in. in external diameter, in lengths exceeding 15 ft. for economiser and superheater boxes for stud tube boilers. These tubes are made from steel having an ultimate tensile strength of 28-32 tons per sq. in. Large quantities of extruded stainless-steel hollows have been produced from 18/11/1 chromium-nickel-titanium steel, for cold drawing by associated companies. They have also made the finished tubes for the heat exchangers. The *Talbot Stead Tube Company, Limited*, likewise of the T.I. group, have also provided seamless stainless-steel tubing for the Calder Hall plant.

Structural Work and Cranes

The supply, delivery and erection of steelwork at Calder Hall has been carried out by *Alexander Findlay and Company, Limited*. They are also responsible for this work in the Calder "B" station and in the similar station at Chapel Cross.

The *Wharton Crane and Hoist Company, Limited*, have supplied the following overhead cranes for Calder Hall "A". In the main turbine hall there is a 60 ton, four-motor crane of 78 ft. span, fitted with an auxiliary hoist of 12 tons capacity. The main hoist is designed to lift 60 tons at 5 ft. per min., but a change-speed gear is incorporated to enable the lifting of 25 tons at 10 ft. per min. The company has provided for the blower houses four 15 ton, three-motor cranes, each with a span of 56 ft. 4 in. At full load they have a hoisting speed of 15 ft. per min., but each crane incorporates the Wharton "Slomax" creep-speed system to provide alternative hoisting speeds of 3 ft. per min. In addition to these five cranes for Calder Hall "A," Wharton's are supplying similar cranes for Calder Hall "B," and also for the Chapel Cross station.

Materials

The *English Steel Corporation, Limited*, have supplied a considerable quantity of 6 in. rolled mild-steel plate for the thermal shield. An illustration showing the shielding in course of erection, together with a description appeared in ENGINEERING on June 29, page 573. Steel has also been produced for various fabricators by *Colvilles Limited*. The heat-exchanger shells, for example, are made from a special grade of steel known as Coltuf 28, provided by this company. The *Consett Steel Company, Limited*, supplied their Lowtem steel for the reactor pressure vessels. General constructional steel was provided by the *Steel Company of Wales, Limited*.

Cooling of the reactor at Calder Hall and the transfer of heat from the reactor to the steam-raising plant, is achieved by forced circulation of pure carbon dioxide gas at moderate pressure (100 lb. per sq. in.) in a closed circuit through the reactor and the steam-generating heat exchangers. The total amount of carbon dioxide in the system is considerable, and the supply of gas, both for the initial filling and for normal operation, presented a number of special problems. Large-scale uses for carbon dioxide already exist in the bottled drinks industry, and many industrial fields. The total usage at Calder Hall necessitates considerable reserves on site, and the only satisfactory method of supply which meets all the requirements is bulk delivery and bulk storage of liquid carbon dioxide, introduced into this country in 1949, by the *Carbon Dioxide Company*, a Division of the *Distillers Company, Limited*. The installation at Calder Hall, supplied and erected by this company, is believed to be the largest single installation so far in operation in the British Isles. It consists of four specially insulated steel tanks, in which a total of 22 tons of liquid carbon dioxide may be stored. Each tank is fitted with an automatic pressure-controlled refrigerator, which cools the liquid to about zero deg. F. (−18 deg. C.) and which also maintains the pressure at 300 lb. per sq. in.

The storage tanks, made by *John Thompson Water Tube Boilers Limited*, are filled by bulk deliveries in the Carbon Dioxide Company's standard road tankers, which carry four tons of liquid at sub-zero temperatures under pressure. The vehicles are filled at one of the company's factories and are discharged at Calder Hall by means of an electrically-driven transfer pump on the vehicle. This pump is powered by a

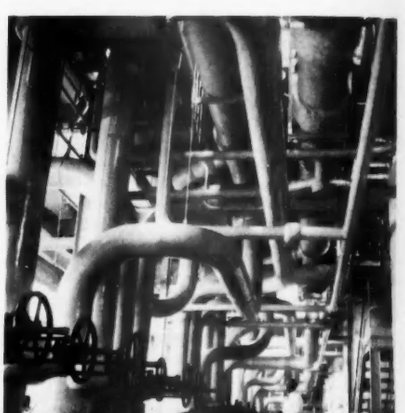


Fig. 45 Basement of the Calder Hall "A" turbine basement, showing complex piping layout.

generator coupled to the tractor engine. Filling or emptying a tanker takes approximately one hour and is carried out without interrupting the normal working of the plant. For use in the reactor circuit, the liquid carbon dioxide is vaporised in four specially designed evaporators, developed and consrtucted by the D.C.L. Research and Development Department in conjunction with engineers of the Atomic Energy Authority. The evaporators consist of two parallel banks of steam-jacketed tubes, the number and size of which were calculated to meet the maximum demand of the system. Each unit can vaporise more than two tons of carbon dioxide an hour. The units are coupled to a manifold, giving a total output of over eight tons an hour when the main circuit is being filled or purged. The same system supplies the smaller quantity of carbon dioxide gas required for normal operation. Constant control is exercised during manufacture of the carbon dioxide, and the system of bulk delivery and bulk storage ensures that there is no loss of quality before the very pure gas is fed into the reactor system.

The problem of lubrication in a nuclear power station is a rather special one and we have already referred to the choice of molybdenum disulphide in the reactor control-rod mechanisms. A number of other lubricants with special properties have also been developed to meet the new conditions imposed. Four years ago, the *Shell Petroleum Company, Limited*, were consulted about lubrication for the Calder Hall

plant by C. A. Parsons and Company, and a programme of experimental work was started at the Shell Thornton Research Centre, Cheshire to evolve the special lubricants required. Irradiation of many materials has been carried out, both in a reactor and by a cobalt 60 source, and lubricants have been developed, capable of withstanding very high temperatures and intense radiation. Another firm concerned in the provision of lubricants is *Wakefield-Dick Industrial Oils Limited.* Transformers built by the Bryce Electric Construction Company are filled with Wakefield-Dick ILO insulating oil, and also those installed at the Windscale grid substation of the C.E.A., which were made by C. A. Parsons and Company, Limited.

COMPANIES CONTRIBUTING

We publish here a list of firms who have contributed either as contractors or subcontractors to the building and installation of Calder Hall "A" nuclear power station.

Construction

ALEXANDER FINDLAY AND CO. LTD., Motherwell, Scotland. (Structural steelwork.)
W. AND J. LEIGH, LTD., Tower Works, Mill Hill, Bolton. (Paint.)
STOTHERT AND PITT, LTD., Bath. (Batching mixers for construction.)
TAYLOR WOODROW CONSTRUCTION LTD., Ruislip-road, Southall, Middlesex. (Main contractor for building and civil engineering work.)
TILGHMANS LTD., Broadheath, Manchester. (Auxiliary shot-blast equipment.)

Pressure Vessels

CHEMICAL AND INSULATING CO. LTD., Darlington, Co. Durham. (Magnesia thermal insulation.)
DARLINGTON INSULATION CO., LTD., 38 Great North-road, Newcastle-upon-Tyne, 2. (Insulation for reactor pressure vessel, heat exchangers and ducting.)
LLOYD'S REGISTER OF SHIPPING, 71 Fenchurch-street, London, E.C.3. (Survey and inspection of pressure plant.)
WHESSOE LTD., 25 Victoria-street, London, S.W.1. (Main contractor for pressure shells for the reactors.)

Heat Exchangers

BABCOCK AND WILCOX, LTD., 209 Euston-road, London, N.W.1. (Main contractor for heat exchangers.)
J. BROCKHOUSE AND CO. LTD., Victoria Works, West Bromwich, Staffs. (Roller bogies for heat exchangers.)
CHESTERFIELD TUBE CO. LTD., Chesterfield, Derbyshire. (Headers for heat exchangers.)
COSTAIN-JOHN BROWN, LTD., 73 South Audley-street, London, W.1. (Heavy lifting gear for site work.)
EDWIN DANKS AND CO. (OLDBURY) LTD., Oldbury, near Birmingham. (Heat-exchanger erection, galleries and ladders.)
DEWRANCE AND CO. LTD., Great Dover-street, London, S.E.1. (Heat exchanger mounting and parallel-slide valves for steam and feed lines.)
ELECTRIC FURNACE CO. LTD., Weybridge, Surrey. (Induction-heating equipment for stress-relieving heat exchangers.)
HAYWARD TYLER AND CO. LTD., Luton, Beds. (Glandless pumps for heat exchangers.)
J. RIGBY AND SONS, LTD., Salford. (Heat-exchanger studs.)
SILICA GEL, LTD., 62 Shaftesbury-avenue, London, W.1. (Dryers used in erection of heat exchangers.)
STEEL CO. OF SCOTLAND, LTD., 132 Blochairn-road, Glasgow, (Thermal sleeves for heat exchangers.)
ST. GEORGES ENGINEERS LTD., Ordsall-lane, Trafford Bridge, Manchester. (Shot-blast plant for heat exchangers.)

Coolant System and Fans

BURNETT AND LEWIS, LTD., 148 High-street, Erdington, Birmingham, 24. (Dryers in coolant circuit.)
CARBON DIOXIDE CO. Devonshire House, Piccadilly, London, W.1. (Carbon dioxide storage plant and evaporators.)
DICK'S ASBESTOS AND INSULATING CO. LTD., London, E.16. (Insulation for coolant storage plant.)
FLUIDRIVE ENGINEERING CO. LTD., Isleworth, Middlesex. (Couplings in coolant blower motor drive.)
JAMES HOWDEN AND CO. LTD., 195 Scotland-street, Glasgow, C.5. (Air blowers for cooling pressure vessel surface and thermal shield.)
MATHER AND PLATT, LTD., Park Works, Manchester, 10. (Main blower motors and motor generators, and water circulating pumps.)
METROPOLITAN REFRIGERATION, LTD., 73 Charterhouse-street, London, E.C.1. (Refrigerating unit.)
STURTEVANT ENGINEERING AND CO. LTD., Southern House, Cannon-street, London, E.C.4. (Dust-Extraction plant.)
JOHN THOMPSON, LTD., Wolverhampton. (Liquid carbon dioxide storage tanks.)
VOKES GENSPRING, LTD., Guildford. (Pipe supports.)

Turbine Plant

HAYWARDS STEEL DOORS, LTD. Union-street, Borough, London, S.E.1. (Steel doors for turbine hall and elsewhere.)
HICK, HARGREAVES AND CO. LTD., Bolton. (De-aerators for feed water.)
HOPKINSONS, LTD., Britannia Works, Huddersfield. (Valves, steam traps, centrifugal oil purifiers, de-superheater control cubicles.)
I.C.I., LTD., London, S.W.1. (Condenser tubes and plates.)
C. A. PARSONS AND CO. LTD., Newcastle-upon-Tyne. (Main contractor for turbo-alternators, dump condensers, and also coolant blowers and circuit.)
G. AND J. WEIR, LTD., Glasgow, S.4. (Feed-water regulators.)

Valves

J. BLAKEBOROUGH AND SONS, LTD., Brighouse, Yorks. (Valves in coolant circuit.)
HAM, BAKER AND CO. LTD., Langley Green, Oldbury. (Penstocks and valves.)

Pumps

PULSOMETER ENGINEERING CO. LTD., Oxford-road, Reading. (Pumps.)

Reactor Control System

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., Trafford Park, Manchester, 17. (Main contractor for control-rod actuating mechanisms.)

Reactor Charging and Discharging

BROOKHIRST SWITCHGEAR, LTD., Northgate Works, Newry Park, Chester. (Electrical equipment for discharge magazine dryer.)
CHATWOOD-MILNER, LTD., Shrewsbury. (Coffins for discharged fuel elements.)
ROYCE ELECTRIC FURNACES, LTD., Sir Richard's Bridge, Walton-on-Thames, Surrey. (Discharge machine magazine air dryers.)
STRACHAN AND HENSHAW, LTD., Steelhoist Works, Bristol, (Main contractor for charge and discharge gear for reactors.)
TANGYES, LTD., Cornwall Works, Smethwick, Birmingham. (Hydraulic ram for lifting lid of burst-slug coffin.)

Reactor Moderator and Fuel

BRITISH ACHESON ELECTRODES, LTD., Grange Mill-lane, Wincobank, Sheffield. (Graphite for moderator.)
FAIREY AVIATION CO. LTD., North Hyde-road, Hayes, Middlesex. (Machining fuel-element cans.)
MATTHEW HALL AND CO. LTD., 26-28 Dorset-square, London, N.W.1. (Laying moderator bricks and work on burst-slug detection equipment.)
POLLARD BEARINGS, LTD., Ferrybridge, Knottingley, Yorks. (Graphite support bearings.)

Reactor Monitoring

DELAPENA AND SON, LTD., Zona Works, Russell-place, Cheltenham, Glos. (Induction-heating equipment for brazing stainless-steel tubes of burst-slug detection gear.)
ELLIOTT BROS. (LONDON), LTD., Century Works, London, S.E.13. (Recorders for burst-slug detection.)
ISOTOPE DEVELOPMENTS, LTD., Aldermaston Wharf, near Reading, Berks. (Reactor gamma monitor.)
MARSTON EXCELSIOR, LTD., Fordhouses, Wolverhampton. (Brazing and cooling arrangements for burst-slug detection gear.)
NASH AND THOMPSON, LTD., Oakcroft-road, Tolworth, Surrey. (Plastic phosphors for scintillation counters.)
PLESSEY NUCLEONICS, LTD., Vicarage-lane, Ilford, Essex. (Main contractor for burst-slug detection equipment.)

Instrumentation

ACCURATE RECORDING INSTRUMENT CO. Aric Works, Garth-road, Morden, Surrey. (Instruments.)
APPLEBY AND IRELAND, LTD., Basingstoke. (Vacuum and pressure measuring devices.)
E. K. COLE, LTD., Southend-on-Sea. (Ionisation chambers and amplifiers.)
HONEYWELL BROWN, LTD., 1 Wadsworth-road, Perivale, Greenford, Middlesex. (Recorders.)
GEORGE KENT, LTD., Luton, Beds. (Recorders and control panels.)
MEASUREMENT, LTD., 119 Union-street, Oldham, Lancs. (Flow indicators.)
NEGRETTI AND ZAMBRA, LTD., 122 Regent-street, London, W.1. (Hygrometers.)
NEW WESTERN (ENGINEERING), LTD., 136 Meadow-lane, Leeds, 11. (Control-room equipment.)
RECORD ELECTRICAL, LTD., Broadheath, Altrincham. (Instruments.)

Electrical

AUTOMATIC TELEPHONE AND ELECTRIC CO. LTD., Strowger Works, Liverpool, 7. (Direct-wire control systems.)
N. G. BAILEY AND CO. LTD., Weaver-street, Leeds. (Electrical installation for lighting and small power.)
BRITISH INSULATED CALLENDER'S CABLES, LTD., 21 Bloomsbury-street, London, W.C.1. (11 kV and fuel-element handling cables.)
BRITISH THOMSON-HOUSTON CO. LTD., Rugby. (Pumpless rectifier units.)
BRYCE ELECTRIC CONSTRUCTION CO. LTD., Kelvin Works, Hackbridge, Surrey. (Transformers.)
CABLE JOINTERS, LTD., 49 Avenue-road, London, W.3. (Cable jointing.)
CHLORIDE BATTERIES, LTD., Clifton Junction, Swinton, Manchester. (Standby battery cells.)
CROSSLEY BROS., LTD., Openshaw, Manchester, 11. (Auxiliary Diesel generators.)
ENGLISH ELECTRIC CO. LTD., Marconi House, Strand, London, W.C.2. (Auxiliary switchgear.)
LANCASHIRE DYNAMO AND CRYPTO, LTD., Trafford Park, Manchester. (Circulating pumps and motors.)
PAROLLE ELECTRICAL PLANT CO. LTD., Princes Buildings, Newcastle-upon-Tyne, 1. (Distribution Switchgear.)
A. REYROLLE AND CO. LTD., Hebburn, Co. Durham. (11 kV generator switchgear with control and ancillary equipment.)
TUDOR ACCUMULATOR CO. LTD., 137 Victoria-street, London, S.W.1. (Battery equipment.)
WESTPOOL, LTD., St. Helens Auckland, Co. Durham. (Solenoids for electrically operated grabs.)
WHIPP AND BOURNE, LTD., Switchgear Works, Castleton, Rochdale, Lancs. (Rectifier equipment for feeding reactor auxiliary equipment.)

Tubes and Ducts

ACCLES AND POLLOCK, LTD., Oldbury, Birmingham. (Stainless-steel tubing.)
AITON AND CO., LTD., Stores-road, Derby. (Steam mains and condensate piping.)
ROBERT JENKINS AND CO. LTD., Rotherham. (Coolant ductwork.)
STEWARTS AND LLOYDS, LTD., Winchester House, Old Broad-street, London, E.C.2. (Tube for heat exchangers, etc.)
TALBOT STEAD TUBE CO. LTD., Green-lane, Walsall. (Stainless-steel tubes.)

Ancillary Items

THE WALTER KIDDE CO. LTD., Lux Works, Belvue-road, Northolt, Middlesex. (Fire extinguishers.)
WHARTON CRANE AND HOIST CO. LTD., Station-road, Reddish, Stockport. (Overhead cranes.)

Materials

COLVILLES, LTD., 195 West George-street, Glasgow. (Coltuf steel for heat-exchanger shells.)
CONSETT IRON CO. LTD., Consett, Co. Durham. (Steel for reactor pressure vessels.)
ENGLISH STEEL CORPORATION, LTD., River Don Works, Sheffield, 9. (Plates for reactor thermal barriers.)
ROCOL, LTD., Swillington, Leeds. (Lubricants for reactor-control mechanisms.)
SHELL PETROLEUM CO. LTD., 1 Kingsway, London, W.C.2. (Special lubricants.)
STEEL CO. OF WALES, LTD., Abbey Works, Port Talbot, Glam. (General constructional steel.)
WAKEFIELD-DICK INDUSTRIAL OILS, LTD., 67 Grosvenor-street, London, W.1. (Insulating transformer oil.)

Obituary

MR. P. V. HUNTER, C.B.E.

"Asdic" Gear and Automatic Cable Protection

We regret to record the death of Mr. P. V. Hunter, which occurred on October 22 at Addington, Surrey, at the age of 73. During the first world war he was concerned with the evolution of the well-known Asdic gear for the location of submarines and during the second invented the buoyant cable, which was so successfully used in the mine sweeping service. He was also responsible for devising the "split conductor" and "four conductor" methods of automatic cable protection and for the "repellent" arc switch, all of which are at present extensively employed.

Philip Vassar Hunter was born in Norfolk and was educated at Wisbech Grammar School and at Faraday House, where he obtained an honours diploma. After acting as assistant engineer to Robert Hammond, he joined the well-known consulting engineers, Merz and McLellan, and was associated with them in building the Carville and Dunston power stations at Newcastle and supervising the erection of a number of waste-heat stations on the north-east coast. He also assisted in the electrification of the Central Argentine Railway, the Buenos Ayres Western Railway and the Melbourne Suburban Railways.

In 1917 Mr. Hunter was appointed engineer to the experimental and research section of the anti-submarine division of the Naval Staff, and with Admiral W. W. Fisher and Sir William Bragg developed the "leader gear" by which ships can be navigated over the route of a cable laid on the bottom of the sea and, as has been said, also evolved the well-known Asdic equipment. He was appointed a Commander of the Order of the British Empire in 1920 for his services in this capacity. In 1919 he joined Callender's Cable and Construction Company Limited as chief engineer and became a member of the board in 1937. In this position he was responsible for many advances in cable design.

Mr. Hunter's association with the Institution of Electrical Engineers began in 1910 when he was elected an Associate Member. He was transferred to the class of member in 1914 and after serving on the Council became president in 1933. His presidential address was mainly concerned with developments in the use of cables for rural distribution. He was elected an Honorary Member of the Institution in 1951 and had also been chairman of the Wiring Regulations Committee. He had done valuable work as chairman of the National Register of Electrical Installation Contractors and had served on committees of the British Standards Institution, the British Electrical and Allied Industries Research Association and the International Electrotechnical Commission. He was a Fellow of the American Institute of Electrical Engineers.

The SNECMA Flying Atar pilotless aircraft in tethered flight at Melun-Villaroche Test Centre. It is controlled from a radio van.

FRENCH "BEDSTEAD" TAKES TO THE AIR

Remotely-Controlled Wingless Aircraft

Shown in the accompanying illustration is the Flying Atar, a remotely-controlled pilotless wingless "aircraft" constructed by Société Nationale d'Etude et de Construction des Moteurs d'Aviation, 150, Boulevard Haussmann, Paris (13e), flying tethered beneath a safety gantry at the Melun-Villaroche Test Centre.

The Flying Atar, which weighs 5,600 lb., comprises a 6,200 lb. thrust Atar turbojet, fuel tanks, and equipment for stabilising and controlling the craft. It can take off, fly vertically and laterally whilst remaining vertical and be landed on a spot chosen by the operator, who works from a radio van where a cockpit is installed. The operator regulates the jet efflux to obtain the required vertical or lateral motion.

The cables, which may be seen in the illustration, are safety devices which do not in any way assist the aircraft, but feed in or out to follow the aircraft's evolutions. They may be brought into action to secure the aircraft in the event of accidental control movements or mechanical failures. In effect, the aircraft is on a "lead" and cannot fly beyond the gantry area.

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RAILS AND BESSEMER STEEL

In this, the centenary year of the introduction of the manufacture of molten steel in quantity, a tribute is paid to Sir Henry Bessemer, F.R.S., by the Workington Iron and Steel Company, branch of the United Steel Companies, Limited, in a sound film in colour, entitled "Steel Road."

After showing examples of several of Bessemer's inventions, and diagrams portraying the gradual development of his steelmaking process, the film depicts the production of Bessemer acid steel at Workington, from the mining of the Cumberland hematite ore to the teeming of the molten steel into ingot moulds. Then follow scenes showing the rolling of the ingots into blooms and finally into rails and their straightening and dispatch. The film ends with a short railway-track laying sequence and a final tribute to Bessemer.

The film, which takes 23¼ minutes to show, is available on free loan, either in the 16 mm. or the 35 mm. form, from the United Steel Companies, Ltd., Westbourne-road, Sheffield, 10.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Housewives' Anticipation of Appliances for the Home in Ten Years' Time," by Miss M. E. Bailey. West London Branch. 134 King-street, Hammersmith, W.6. Tues., Nov. 6, 7.30 p.m.
"Fluorescent Lighting Circuits and the Servicing of Fluorescent Fittings," by G. V. McNeill. North London Branch. 677 Green Lanes, Harringay, N.4. Wed., Nov. 7, 7.45 p.m.
ILFORD
"Discussion on 13th Edition I.E.E. Regulations," by E. J. Sutton. North East London Branch. Angel Hotel, Ilford. Mon, Nov. 5, 7.30 p.m.
LUTON
"Automatic Relays and Controls, with Special Reference to Radioactive Isotopes," by Dr. W. L. Stern. Luton Branch. Chamber of Commerce, George-street West, Luton. Tues., Nov. 6, 8 p.m.
MANCHESTER
Discussion on "Electricity in the Newspaper World." Manchester Branch. Engineers' Club, Albert-square, Manchester. Wed., Nov. 7, 7.30 p.m.
READING
"Electronic Measuring Instruments," by R. Postle. Oxford and Reading Branch. The University, London-road, Reading. Tues., Nov. 6, 7.15 p.m.

British Institution of Radio Engineers

GLASGOW
"Oscilloscope for Engine Testing," by R. K. Vinycomb. Scottish Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., Nov. 8, 7 p.m.
LIVERPOOL
"Industrial Television," by J. E. H. Brace and R. Swinden. Merseyside Section. Chamber of Commerce, 1 Old Hall-street, Liverpool 3. Wed., Nov. 7, 7 p.m.

Building Centre

LONDON
Films on "Follow the Wire" and "Building Britain's Grid." Wed., Nov. 7, 12.45 p.m.

Chemical Society

BANGOR
"Allene Chemistry," by Professor E. R. H. Jones. North Wales Branch. Department of Chemistry, University College of North Wales, Bangor. Thurs., Nov. 8, 5.45 p.m.
CAMBRIDGE
"Atomic Radiation and Polymers," by Dr. A. Charlesky. Cambridge Branch. University Chemical Laboratory, Lensfield-road, Cambridge. Fri., Nov. 9, 8.30 p.m.
OXFORD
"Organometallic Compounds," by Professor G. E. Coates. Oxford Branch. Physical Chemistry Laboratory, South Parks-road, Oxford. Mon., Nov. 5, 8.15 p.m.

Combustion Engineering Association

GLASGOW
Various papers on "Oil Firing of Industrial and Commercial Boiler Plants." Berkeley Hall of St. Andrew's Hall, Glasgow. Thurs., Nov. 8, 10 a.m. and 2.30 p.m.

Illuminating Engineering Society

CARDIFF
"Use of Coloured Light," by H. Hewitt and C. R. Passmore. Cardiff Centre. Offices of the South Wales Electricity Board, The Hayes, Cardiff. Thurs., Nov. 8, 7 p.m.
EDINBURGH
"Design To-Day," by A. Maynard. Edinburgh Centre. Y.M.C.A., 14 South St. Andrew-street, Edinburgh. Wed., Nov. 7, 6.15 p.m.
NEWCASTLE-UPON-TYNE
"Television Studio Lighting Equipment," by K. R. Ackerman. Newcastle-upon-Tyne Centre. King's College, College-road, Newcastle-upon-Tyne 1. Wed., Nov. 7, 6.15 p.m.

Incorporated Plant Engineers

LONDON
"Use of Radio Isotopes in Industry," by C. W. Jones. London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., Nov. 6, 7 p.m.*
EDINBURGH
Discussion on "Choice of Pumps." Edinburgh Branch. 25 Charlotte-square, Edinburgh. Tues., Nov. 6, 7 p.m.
GLASGOW
"An Introduction to Atomic Energy," by J. A. Dixon. Glasgow Branch. Scottish Building Centre, 425-427 Sauchiehall-street, Glasgow. Thurs., Nov. 8, 7.15 p.m.
NEWCASTLE-UPON-TYNE
"Engineering Economics," by T. S. Welch. North East Branch. Roadway House, Oxford-street, Newcastle-upon-Tyne. Thurs., Nov. 8, 7 p.m.
PORTSMOUTH
"Noise," by E. J. Richards. Southern Branch. Carnegie Library, Fratton-road, Portsmouth. Wed., Nov. 7, 7.30 p.m.

Institute of British Foundrymen

LUTON
"Mechanising a Small Jobbing Foundry," by R. H. Blandy. Bedfordshire and Hertfordshire Section. Town Hall, Luton. Thurs., Nov. 8, 7.30 p.m.
MANCHESTER
"Fast Drying Bonding Materials," by A. I. Donaldson. Lancashire Branch. Midland Hotel, Manchester. Mon., Nov. 5, 7 p.m.
SHEFFIELD
"Training," by O. W. Reynolds; and "Foundry Training," by H. Parkin. Sheffield Branch. Sheffield College of Commerce and Technology, Pond-street, Sheffield, 1. Mon., Nov. 5, 7 p.m.

Institute of Industrial Supervisors

COVENTRY
Discussion on "The Foreman's Future." Coventry Section. Sibree Hall, Warwick-row, Coventry. Tues., Nov. 6, 7.30 p.m.

Institute of Marine Engineers

LONDON
Film Evening. Student Meeting. Mon., Nov. 5, 6.30 p.m.*
LIVERPOOL
"Metallurgical Problems in Marine Engineering," by B. Todd. Merseyside and North Western Section. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Mon., Nov. 5, 6.30 p.m.
NEWCASTLE-UPON-TYNE
"The Selectable Superheat Boiler," by R. E. Zoller. North East Coast Section. Stephenson Building, King's College, Claremont-road, Newcastle-upon-Tyne. Thurs., Nov. 8, 6.15 p.m.*

Institute of Metals

BIRMINGHAM
"The Metallurgy of Steel for Deep Drawing and Pressing," by A. J. K. Honeyman. Birmingham Local Section. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Thurs., Nov. 8, 6.30 p.m.
OXFORD
"Radiation Damage," by Dr. A. T. Churchman. Oxford Local Section. Cadena Café, Cornmarket-street, Oxford. Tues., Nov. 6, 7 p.m.

Institute of Petroleum

LONDON
Symposium on "Digital Computers in the Petroleum Industry." Wed., Nov. 7, 3 p.m. (Tea at 5 p.m.)

Institute of Road Transport Engineers

BRISTOL
"Air Brakes and Auxiliaries for Commercial Vehicles," by W. A. Kirk. Western Centre. Royal Hotel, Bristol. Wed., Nov. 7, 7.30 p.m.
GLASGOW
"The Pneumo-Cyclic Gearbox," by J. Milloy. Scottish Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Mon., Nov. 5, 7.30 p.m.
LIVERPOOL
"Service Methods and Construction of Commercial Vehicles," by C. H. Rowley. West Regional Centre. Adelphi Hotel, Lime-street, Liverpool. Tues., Nov. 6, 7.30 p.m.
NOTTINGHAM
"Piston Design and Maintenance," by L. Howell. East Midlands Centre. Mechanics' Institute, Nottingham. Wed., Nov. 7, 7.30 p.m.

Institution of Chemical Engineers

LONDON
Symposium on "Grinding." Royal Institution, 21 Albemarle-street, W.1. Wed., Nov. 7, 3 p.m.

Institution of Civil Engineers

LONDON
Presidential Address by H. J. F. Gourley. Tues., Nov. 6 5.30 p.m.*
BIRMINGHAM
"Aspects of Traffic in America," by N. P. Brand. Midlands Association. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Nov. 8, 6 p.m.
EDINBURGH
"British Highway Bridge Loading," by W. Henderson. Edinburgh and East of Scotland Association. North British Hotel, Edinburgh. Wed., Nov. 7, 6 p.m.

Institution of Electrical Engineers

LONDON
"Electric Strength of Highly Compressed Gases," by Dr. E. H.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Combustion Engineering Association, 6 Duke-street, St. James's, London, S.W.1. (WHItehall 5536.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Industrial Supervisors, 24 Albert-street, Birmingham 4. (Midland 6971.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 17 Belgrave-square, London, S.W.1. (BELgravia 3291.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of Chemical Engineers, 16 Belgrave-square, London, S.W.1. (BELgravia 3647.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Manchester Association of Engineers, 18 Booth-street, Manchester 2. (Central 1717.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2365.)
Sheffield Metallurgical Association, 66 Ringstead-crescent, Sheffield 10. (Sheffield 62144.)
Society of Chemical Industry, 14 Belgrave-square, London, S.W.1. (BELgravia 3681.)

Holt (to be read by Dr. H. Tropper); and "Insulation Properties of Compressed Electro-Negative Gases," by Dr. P. R. Howard. Measurement and Control Section. Tues., Nov. 6, 6.30 p.m.*
"Visit of the British Electricity Supply Delegation to the Soviet Union," by J. Eccles. Thurs., Nov. 8, 5.30 p.m.*
BIRMINGHAM
"Potentialities of Railway Electrification at the Standard Frequency," by E. L. E. Wheatcroft and H. J. C. Barton. South Midland Centre. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., Nov. 5, 6 p.m.*
LEEDS
"Highland Water Power," by the late T. Lawrie. North Midland Centre. 1 Whitehall-road, Leeds. Tues., Nov. 6, 6.30 p.m.
LIVERPOOL
"American Power Station Practice," by G. F. Kennedy. Mersey and North Wales Centre. Liverpool Royal Institution, Colquitt-street, Liverpool. Mon., Nov. 5, 6.30 p.m.
MANCHESTER
"Conduction and Induction Pumps for Liquid Metals," by Dr. L. R. Blake. North Western Centre. Engineers' Club, Albert-square, Manchester. Tues., Nov. 6, 6.15 p.m.

Institution of Engineering Designers

LONDON
"Demands of Efficient Human Reaction on Engineering Design," by D. E. Broadbent. Thurs., Nov. 8, 6.45 p.m.
NEWCASTLE-UPON-TYNE
"Design and Application of Centrifugal Pumps," by D. W. Coleman. North East Branch. 6 Higham-place, Newcastle-upon-Tyne 6. Mon., Nov. 5, 7.15 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Operation of an Oil Refinery," by J. G. Annan. Tues., Nov. 6, 6.30 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"Heating and Hot-Water Supply and Demand in Flats," by K. W. Dale. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Nov. 7, 6 p.m.*
LEICESTER
"Water Treatment for the Heating Engineer," by F. R. Jarrett. East Midland Branch. College of Technology, Leicester. Wed., Nov. 7, 6.45 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "Extent to which Lubrication Should Enter into First Degree and Higher National Certificate Courses." Education and Lubrication Groups. Thurs., Nov. 8, 6.45 p.m.*
"Rotating Beam Channel and 30 in. Water Tunnel at the Admiralty Research Laboratory," by E. H. Lever, H. Ritter, M. Woolfson and C. T. Wright. Meeting in conjunction with the Hydraulics Group. Fri., Nov. 9, 6 p.m.*
HALIFAX
"Some Experiments on the Deflections and Vibrations of Drilling Machines," by Dr. D. V. Galloway. Yorkshire Branch. White Swan Hotel, Halifax. Thurs., Nov. 8, 7 p.m.
MANCHESTER
"A Criticism of the Technical Education of Recently Qualified Engineers," by P. P. Love. North Western Branch. Engineers' Club, Albert-square, Manchester. Thurs., Nov. 8, 6.45 p.m.
NEWCASTLE-UPON-TYNE
"Nuclear Reactors and Power Generation," by B. L. Goodlet. North Eastern Branch. Literary and Philosophical Society, Westgate-road, Newcastle-on-Tyne. Mon., Nov. 5, 6.15 p.m.

Institution of Production Engineers

GLOUCESTER
"Protection Processes," by R. Gillanders. Gloucester Section. Technical College, Brunswick-road, Gloucester. Fri., Nov. 9, 7.30 p.m.
ILFORD
"New Metals, Including Titanium, Zirconium and Molybdenum," by Dr. T. W. Farthing. South Essex Section. Wed., Nov. 7, 7.30 p.m.

Institution of Structural Engineers

LONDON
"Elliott Secondary School, Putney," by Walter C. Andrews. Thurs., Nov. 8, 6 p.m.
BELFAST
"Gasholder Development and Design," by W. R. Garrett. Northern Ireland Branch. College of Technology, Belfast. Tues., Nov. 6, 6.45 p.m.
COLWYN BAY
"Modern Steelwork Fabrication," by G. E. Cooper. Wales and Monmouthshire Branch. County Buildings, Colwyn Bay. Sat., Nov. 10, 6 p.m.
SWANSEA
"Modern Steelwork Fabrication," by G. E. Cooper. Wales and Monmouthshire Branch. Mackworth Hotel, Swansea. Wed., Nov. 7, 6.30 p.m.

Junior Institution of Engineers

LONDON
Chairman's Address on "Some Aspects of Repairs to Airframes," by J. C. Y. Baker. Fri., Nov. 9, 7 p.m.*

Manchester Association of Engineers

MANCHESTER
"Design and Development of the Deltic Engine," by C. D. Carmichael. Engineers' Club, Albert-square, Manchester. Fri., Nov. 9, 6.45 p.m.

Royal Aeronautical Society

LONDON
"London Airport," by Air Marshal Sir John D'Albiac. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Tues., Nov. 6, 6 p.m.*

Royal Institution

LONDON
"Optics in Industry." IV—"Miscellaneous," by Dr. A. C. Menzies. Tues., Nov. 6, 6 p.m.

Royal Society of Arts

LONDON
Chairman's Inaugural Address on "Whither Design: A Layman's View," by Dr. R. W. Holland. Wed., Nov. 7, 2.30 p.m.

Sheffield Metallurgical Association

SHEFFIELD
"Modern Trends in Metallurgical Analysis," by W. T. Elwell. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield 3. Tues., Nov. 6, 7 p.m.

Society of Chemical Industry

LEEDS
"Stress Corrosion of Steel in Caustic Soda Solutions," by F. A. Champion. Yorkshire Section and Corrosion Group. Chemical Lecture Theatre, The University, Leeds. Mon., Nov. 5, 7 p.m.

ATOMIC REVIEW

Operating Atomic Plant

Without doubt the greatest problem that has arisen in the operation of atomic plant is that of safety. Last week's article referred to the bitter controversy going on among medical men and among nulear physicists on the dangers to public health. Some make light of it and consider the problem already solved, others see in it a threat to the continuation of humanity. Few know enough to be quite sure of their ground. So far, operations have been on a small scale and little can be known of the magnitude of the problems which atomic energy operators will have to face as more plants are commissioned. A great deal, however, is known about their nature.

Built-in Protection

The Atomic Energy Authority have led the way in the design of safe plant and shown a constant awareness of the risks involved. The Medical Research Council's recent report *The Hazards to Man of Nuclear and Allied Radiations* commented that this awareness and the care with which the risk is being met give "justifiable grounds for reassurance." There are two major problems: the first is to ensure that reactors can be operated safely and the second—by far the most difficult—is to eliminate the risk of contamination from the irradiated fuel when it is removed from the reactor for processing and disposal.

When a reactor is running, neutrons arise from the fission reaction which have sufficient power to pass through the whole thickness of the body and so irradiate all the tissues more or less evenly. Reactors are therefore designed to embody a biological shield which consists of radiation-absorbing materials, such as concrete, lead or steel. The thickness of the layer is determined by the type and intensity of radiation and by the absorptive qualities of the shielding material. Of these, concrete has been found the most economical for large shields. At Calder Hall, for example, the reactors have been enclosed in walls of concrete 7 ft. thick which reduce the radiation intensity to a harmless level outside the reactor. The danger from plant explosion or failure is said to be negligible. A possible hazard is the possibility of the failure of a fuel element, resulting in the release of large quantities of fission products into the coolant system and endangering operating personnel. The development of "burst-slug" detection gear, which detects signs of element fracture long before it takes place, has considerably reduced the danger if not completely eliminated it.

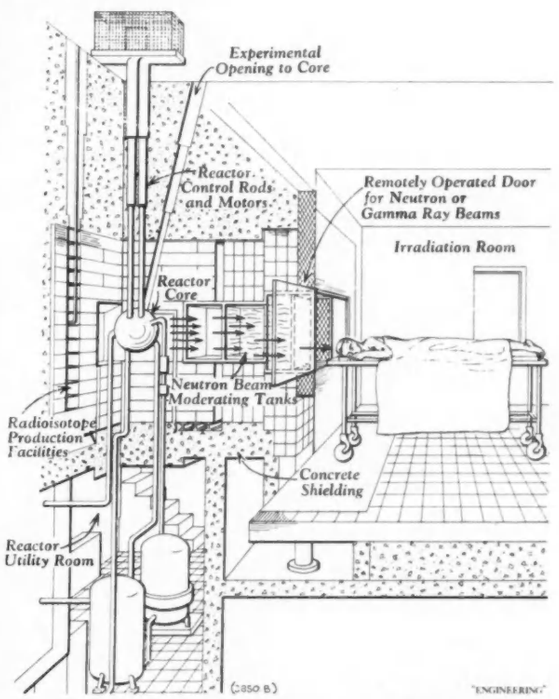
In order to avoid the contamination which would occur when irradiated fuel is removed from the plant, each piece of uranium—the element—is clad in a sheath of suitable material, such as zirconium or beryllium. Periodically the elements are removed intact for transport to processing plants to recover the unused fuel material, remove fission by-products and to recover plutonium. For removal they are placed in thick lead boxes, since the bulk of concrete needed to give the equivalent protection would make transport almost impossible.

The chemical processes for the treatment of used fuel are carried out at separate plants away from the reactors. This makes possible the complete isolation of this complicated and difficult process, which carries far greater risks of radio-active contamination (by gamma rays given off by the fission products present in irradiated fuel), than from the operation of reactors. The atomic energy programme of the Central Electricity Authority contains special provision for carrying out by-product recovery and processing in locations remote from the proposed power stations.

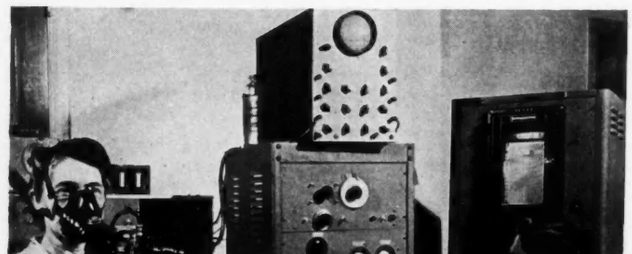
Remote and Automatic Control

In the handling of irradiated fuel it is essential to avoid the spread of contamination by radio-active substances which might be breathed or swallowed by workers. This has been achieved by the introduction of remote controls and the automation of the more dangerous processes. Another important principle of plant design consists of limiting the radiation exposure by controlling the duration of certain jobs where it tends to be high. Few processes offer as powerful an incentive to the introduction of automatic techniques and it is likely that within a relatively short time the chemical processing plants will be run with very few workers.

The group medical officer (Industrial Group) of A.E.A. commented recently that "A prerequisite of good reactor-plant management is the accurate and continuous assessment of the type and intensity of radiation in work areas, and of the exposure of each individual employee." This is achieved by an elaborate network of recording instruments. The exposure of workers is recorded by means of small photographic films which each worker carries, and—for non-routine operations and maintenance work—by means of small pocket dose-recorders. These methods make possible a very close control of the rate of exposure of each employee, and should therefore ensure complete safety. They also constitute continuous records which assist plant designers to develop increasingly safer plant and processes.



A drawing of the treatment room and medical reactor to be built at the University of California. The 50 watt reactor will be used for diagnosis and treatment and also for studying the preservation of food and drugs.



Metobolic diseases can be readily diagnosed with this equipment which records the radioactivity of the exhaled breath of a patient who has been given one of a number of isotopes.

Disposal of Waste Materials

Waste products, which arise in liquid, gaseous and solid form, present a problem which is likely to increase with the rate of operations. The two fundamental ways of disposing of radio-active waste are, on the one hand, by dispersal to safe levels and disposal in the natural environment, and on the other, by concentrating radio-active components into a stable chemical and physical form and a small volume for storage. Chemical treatment for liquid wastes, incineration or baling for solids, and filtration for gases enable both methods to be used successfully. It is the designer's problem to keep the amounts of radioactivity in such waste to a minimum, and to treat the production and disposal of the waste as an integral process so that it is produced in a form suitable for disposal. The importance of good design was emphasised recently by Mr. H. J. Dunster of the Health Physics Division, Atomic Energy Research Establishment, Harwell, in the following terms: " When designing equipment and processes for the handling of radio-active materials consideration must be given to safety from direct radiation and contamination, concomitant with flexibility of operation and feasibility of maintenance."

What Remains to be Done

In a major report on the effects of radiation published last July, the United States National Academy of Sciences made the following recommendations concerning the broad directions which should be followed to ensure safety from radiation hazards:

(1) Until advances in reactor technology substantially reduce potential hazards, buildings that house reactors located near populated areas should be sealed against the release of radioactive materials in the event of accident.

(2) Research should be accelerated, particularly on safety devices for control of accidental power surges in reactors; the selection of biologically suitable sites for various nuclear facilities; the geophysical and geochemical aspects of ultimate disposal of radioactive wastes; and mixing between various parts of the oceans and of the atmosphere.

(3) A national agency should control and keep records of all dumping of radio-active material in the ocean. An international body should set up safe standards for the marine and air disposal of radio-active materials as soon as possible, based on current knowledge. Research on marine disposal should be carried out on a co-operative international basis.

(4) Records should be kept for each individual showing his total accumulated lifetime exposure to radiation. Medical use of X-rays should be reduced as much as is consistent with medical necessity.

(5) Techniques for monitoring world-wide fall-out should be further improved. Measurements of the storage of radiation in the stratosphere should be extended.

These, and further improvements in design of nuclear plant and in the processing of waste materials, should make the atomic age safe for human beings. Clearly enough remains to be done to make any complacency on the present position very much out of place.

Contribution to Medicine, Biology and Agriculture

Already the development of nuclear fission has made a major contribution to health and food supplies. The use of isotopes and radiations for the diagnosis and treatment of cancer and tumours is increasingly rapidly, as is their use in genetics. Irradiation of seeds and pollen increases the natural mutation rate many times and in this way an oat resistant to infection by most fungi has been produced in the United States. There is little doubt that the development of the applications of radio-active materials has been held back so far only by their availability at reasonable cost. Rapid progress can be expected: so far most has probably been made in the United States and Soviet Russia. In both countries the use of radio-active cobalt has been found particularly effective and considerable advantages are claimed over radium in therapy. The United States has several nuclear medical centres in the building or planning stage. The first, due to be completed towards the end of 1956, is at the University of California School of Medicine, Los Angeles. Its specially designed reactor, illustrated on page 571, will provide radiation for cancer research and treatment. The equipment illustrated on this page is one of a very comprehensive range now available for diagnosis work. The United States Atomic Energy Commission announced that another medical research centre was to be constructed at their Brookhaven Laboratory, where for the past six years a reactor has been in part-time use for the treatment of brain tumours. The Brookhaven dilution centre will occupy over 100,000 sq. ft. and be equipped with a new reactor to provide a neutron source for work on brain cancer. Radio-tracer work in biochemistry and physiology in animals and plants has also been considerably advanced. The use of ionisation radiations on the improvement of crops and on the cold sterilisation of foods are developments which could prove of major significance in the next decade. Over a year ago at Geneva a paper given by members of the Massachusetts Institute of Technology predicted the commercial use of irradiation sterilisation of more pharmaceuticals, foods, tissues and packaging materials within a few years.

Legal Considerations

Hitherto there has been little legislative control of the operation of nuclear plants beyond the general conditions of enactments such as the Radioactive Substances Act and the Factories Acts, but consideration is now being given to specific regulations. So far as public health is concerned the only specific legal provisions at present are those requiring the A.E.A. to ensure that no damage to persons or property is caused by ionising radiations in material used on their premises or discharged from them, and to deal with its waste disposal problems in accordance with authorisations granted in England by the Ministry of Housing and Local Government and the Ministry of Agriculture, Food and Fisheries, and in Scotland by the Secretary of State. It may be assumed that the same provision will apply to the C.E.A.'s nuclear plants though new and more comprehensive legislation will doubtless be evolved over the next few years. Indeed, last September, in the United States, the University of Michigan Law School began discussions to evolve " conclusions and recommendations on emerging unique legal problems."

Depreciation and Insurance

The question of insurance was studied recently by a joint committee of Lloyds underwriters who recommended that the C.E.A.'s first atomic power station should be fully underwritten. The committee visited Harwell, Risley, and Calder Hall and concluded that the risk of nuclear explosions was negligible. In their view British Insurance companies need not be unduly concerned at taking on this type of insurance. The British Insurance Association agreed with these findings and considered the insurance of risks from industrial use of atomic energy is " a practical possibility " though they pointed out that there was " a new hazard in the shape of possible radio-active contamination." In the United States limited government cover will be required, but less so than had been originally envisaged; it will be limited to cases where catastrophic damage occurs, admitted to be an unlikely eventuality.

The record annual report of the A.E.A. (Appendix 3, para. 8) gave the figures used for calculating plant amortisation. Ten per cent. per year was quoted for the reactor and chemical process plant and equipment, which compares with the 15-year life estimated by the Economic Advisor to the A.E.A., Professor Jukes, in the paper he gave to the Geneva conference. It is probable, however, that the life of the plant will be higher in industrial undertakings than in research establishments, though there is experience on which to base an estimate.

The problems attendant to the running of an atomic plant are many and some are very complex, but the progress made in the past 10 years suggests that none is likely to defy solution for very long. The keen awareness of the problems by the industry's designers is its greatest asset and a good insurance against the many hazards of the atomic age.

* * *

NEW FACTORY FOR HOT BRASS FORGINGS AND PRESSINGS

The Sanbra Group comprises a number of companies in the Midlands. Until recently, one of the companies was located at Cwmbran, Monmouthshire, but as part of an overall plan to ensure greater efficiency within the Group, the Cwmbran company, Hot Pressed Products, has been transferred to Great Bridge, Tipton, Staffordshire. All the Group's factories are now within a few miles of each other. Administration has been simplified and transport charges have been reduced and, in addition, certain facilities such as machining, and tool and die designing and making can now be made available if required to all the companies within the Group. The new Hot Pressed Products factory has been built on virgin land, and advantage has been taken of the opportunity to design a simple and efficient layout. The production flow through the factory, which is in full operation on hot brass pressings to customers' designs, is in the form of a letter U, the receiving and dispatch departments being on the same side of the building.

Heat and fumes from the various forging and pressing operations are cleared by a combination of exhaust and intake fans, which deal effectively with all conditions of temperature and atmosphere; as a result, the press shop is free from fumes at all times. Facilities are provided for acid pickling, washing and drying of pressings, if required, in a pickling section which is separated from the main production flow line, and equipped with its own fume-extraction plant.

PROGRESS IN AUTOMOBILE DESIGN

By Gordon Wilkins

The main feature of car engine design on 1957 British models—a useful if not spectacular one—is an increase in compression ratio which, sometimes combined with other improvements, has raised maximum power outputs 10 to 15 per cent., with an accompanying increase in torque. Britain is now second to the United States in utilising the potential of modern high-octane fuels. American designs using compression ratios up to 10 to 1 are achieving specific outputs around 50 b.h.p. per litre, and brake mean effective pressures of over 160 lb. per sq. in. on touring car engines. Of the two cheapest American makes, Ford now offers an optional 312 cub. in. V8 engine giving 245 b.h.p. on the test-bed, and Chevrolet offers a 283 cub. in. engine with fuel injection giving up to 250 b.h.p.

FUEL INJECTION

The Chevrolet injection system, built by Rochester, sprays fuel through injectors close to the inlet ports. Air passes through a fixed Venturi, and then through a conventional butterfly throttle. The pressure difference between the two points controls a metering device with a float chamber fed by a normal diaphragm pump. A high-pressure gear-type pump, worked from the ignition distributor drive, takes fuel from the float chamber and delivers it through a valve controlled by the air flow, to eight nozzles adjacent to the inlet ports. The nozzles have air bleeds to ensure that fuel is delivered at atmospheric pressure, regardless of manifold pressure fluctuations.

Constant increases in the power delivered by American engines have caused adverse criticism by interests concerned with road safety, and senior executives of the motor manufacturers have recently testified to the heavy losses which reduce the power available at the road wheels. Typical figures quoted in an S.A.E. discussion for maximum power output were: fan, 7 b.h.p.; generator and power steering 2½ b.h.p. each; air conditioning equipment, 11 b.h.p.; and losses in the automatic transmission, 12 b.h.p. Air conditioning, if complete with a refrigeration unit, is a particularly expensive luxury, as it usually involves stronger springs, and tyres of larger section to carry the weight.

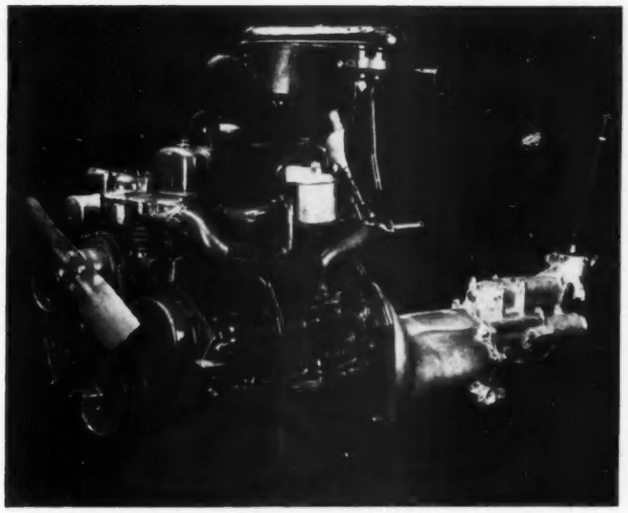
Even in the United States, where incomes are high and fuel cheap, there has been some criticism of heavy fuel consumption, and on recent models a rise in compression ratio has been accompanied by a lower numerical axle ratio, so that some cars, with axles of 2·9 or 3 to 1 are now doing 24 miles per Imperial gallon at 60 m.p.h. The same process has yielded big dividends on several B.M.C. models, such as the Morris Minor 1,000, Austin A35, and Wolseley 15/50, where larger engines have been accompanied by an important reduction in steady-speed fuel consumptions.

There are indications that American designers are now reaching the limit of what can be achieved from present fuels, without radical improvement of combustion chamber design. Fuels produced by catalytic re-forming have tended to show a wide spread between octane ratings obtained by research and motor methods, and with present engine installations it is the more severe motor rating which seems to give the closest correlation with road load conditions.

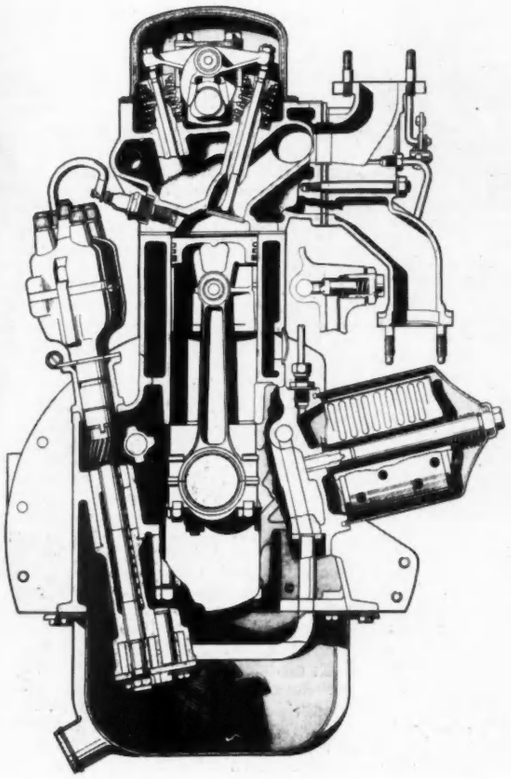
Fuel injection is regarded as a future method of reducing bonnet height in accordance with the ever lower lines of American cars, but meanwhile engine height is being reduced by enclosing the carburetters within a new type of throw-away pleated paper air filter, which has a life of about 20,000 miles. It is said to be more efficient than an oil-bath cleaner at its best, and has a higher safety factor as it gives warning of clogging by a reduction in engine performance, whereas a neglected oil bath may cease to function without warning.

SUPERCHARGED ENGINE

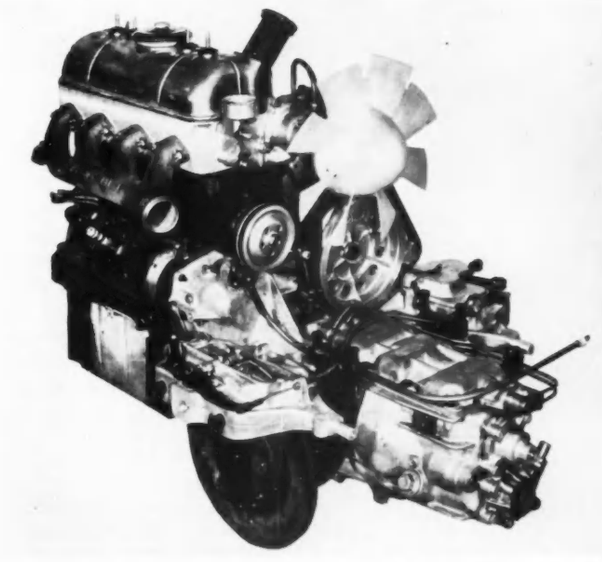
Studebaker, who have been unable to arrest the decline in their overall share of the American market, have had some success with their coupé models, of somewhat European appearance, which accounted for 25 per cent. of 1956 production. The most powerful car, the Golden Hawk, no longer uses the big Packard V8 which gave 279 b.h.p. from 5·7 litres, but have substituted a smaller lighter unit of 4·7 litres, and use a McCullouch belt-driven supercharger to step up maximum power to 275 b.h.p. Super-



The B.M.C. 950 c.c. engine, as used on the Morris Minor.

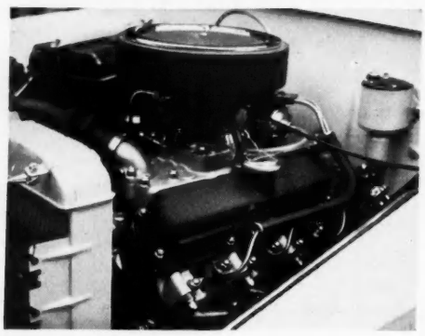


Singer 1,500 c.c. engine incorporated in the Gazelle.

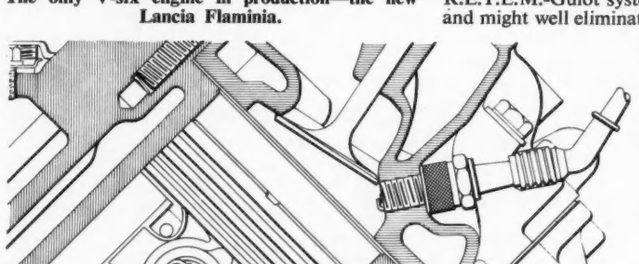


Citroen DS19 engine-transmission unit, now manufactured in England.

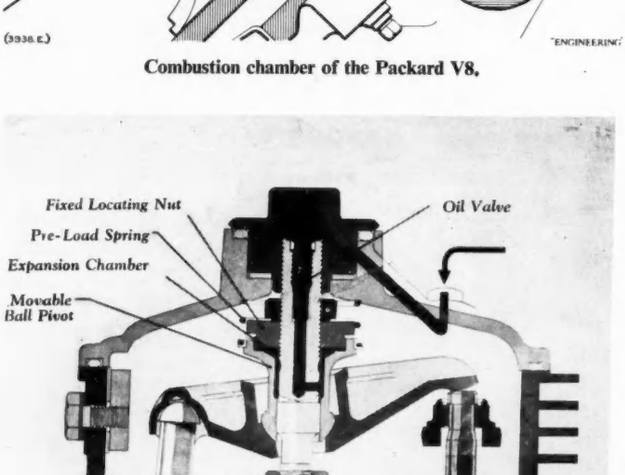
charger speed is varied by a piston, subject to manifold depression, which varies the distance between the pulley flanges, and hence its effective diameter. The supercharger thus takes relatively little power at cruising speeds, but speeds up whenever the throttle is opened suddenly, as, for example, during acceleration or hill climbing.



The only V-six engine in production—the new Lancia Flaminia.



Combustion chamber of the Packard V8.



Twin-cylinder engine of the French Dyna Panhard.

IGNITION

In the ignition field, there has been little development of conventional equipment beyond a Ducellier distributor, exhibited in Paris, which has the vacuum control linked to the moving contact arm in such a way that the points are displaced laterally by a small mount in relation to each other. It is said to prevent pitting, without appreciably altering the working gap. A more far-reaching development also shown at Paris was an electronic ignition to replace the conventional electromechanical system. The flux generated by a suitable rotating element, as shown in the diagram on the right, is used to modulate a transistor wired as a blocked oscillator. The output from the oscillator is passed through a transformer which steps it up to the voltage required for the sparking plugs. The conventional mechanical distributor loses efficiency at high rotational speeds, which can only be overcome by additional complication. The R.E.T.E.M.-Guiot system is extremely compact, and might well eliminate one of the most fruitful sources of breakdown on the road. Oil and water have little effect, and a very small battery current is sufficient to operate it. Suppression problems are also reduced by the limited frequency range of the high-tension impulses.

Electronic ignition is no novelty: General Motors and R.C.A. have various patents on the subject, but use discharge tubes or thyratrons. Various manufacturers are now trying out this new system, to see whether the transistor can fulfil the promise of reliable ignition at all speeds, with minimum current consumption and freedom from mechanical problems.

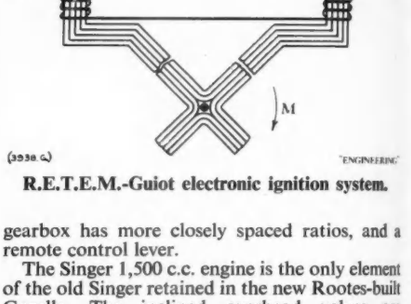
Compactness and good balance have established the overhead-valve V8 as the standard American production engine, and large-scale tooling has brought production costs down level with or even below those for an in-line six, but the type still makes no headway in Europe, where outputs could not support the degree of tooling necessary to manufacture it economically. The only European example in large quantity production is the Simca Versailles, an adaptation of a pre-war side-valve Ford design. The only one with overhead valves is the B.M.W., made with two sizes of bore to give 2½ or 3·2 litres. This is a modern design, with wet sleeves in a light-alloy block, and a heat exchanger for the lubricating oil in the water system.

The steady advance in the use of light alloys on American cars may embrace the cylinder block if the claims of the Doehler Jarvis company are realised. They are planning to die-cast aluminium six-cylinder blocks weighing 43 lb. machined against 175 lb. for grey iron, and are working on methods of producing V8 blocks weighing about 75 lb.

GAS TURBINES

All work on piston engines comes increasingly under the shadow of the gas-turbine as exemplified by the Rover T3 experimental car. Use of a plate-type secondary-surface contra-flow heat exchanger has enabled fuel consumption of the 110 h.p. unit to be brought down to 14·3 m.p.g. at 60 m.p.h., but the exhaust still emerges at about 200 deg. C. and the engine compartment is lined with asbestos. The Renault Shooting Star, also exhibited at Earls Court, is much farther from a practical road car, but by establishing new turbine car speed records at Bonneville, Utah, at 192 m.p.h. it has achieved extensive publicity and drawn attention to the possibilities which will be more fully exploited by Mr. Donald Campbell in his planned attack on the absolute world speed record with a Bristol Proteus turbine.

The following detail points of design are brought out in the illustrations to this article. Although closely following established B.M.C. design, the 950 c.c. engine for the Morris Minor 1,000 and Austin A35 is an entirely new unit, with lead-indium big-end bearings. The new gearbox has more closely spaced ratios, and a remote control lever.



R.E.T.E.M.-Guiot electronic ignition system.

The Singer 1,500 c.c. engine is the only element of the old Singer retained in the new Rootes-built Gazelle. The inclined overhead valves are operated from a single chain-driven camshaft. The engine transmission unit of the Citroen DS 19, now assembled in England, has inclined valves in hemispherical combustion chambers, operated by crossed rockers. The nylon fan and inboard disc brakes are also shown in the illustration. The only V-six engine in production now appears in the new Lancia Flaminia, with single downdraught carburetter on a water-heated manifold and thermostatically controlled radiator shutters.

The illustration of the combustion chamber of the Packard V8 engine, which has a 10 to 1 compression ratio, shows the long-reach sparking plug and the piston with flat top, cut-away skirt and three rings. On the French Dyna Panhard twin-cylinder engine, valve clearance is taken up hydraulically by loading the ball rocker pivot—a simpler method than taking oil to moving tappets as is the American practice.

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STEELS IN A MODERN CAR

The close and continuous tie which exists between the engineering and the steelmaking industries in the production and erection of a modern motor car is illustrated in a new black and white sound cinema film, entitled "The Birth of a Car" now released for exhibition by the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1.

The film shows each stage in the manufacture of a motor car from the assembly of the differential to the final lowering of the body on to the engine and front axle. It is stated that no fewer than 32 different kinds of steel go to make

the 19,000 parts in a modern car, and that, on an average, about one ton of finished steel is used in the production of each vehicle. It is also pointed out that one of the heaviest demands for steel in this country is made by the body-building plants of the motor-car industry.

The film, in either the 16 mm. or the 35 mm. form, runs for 25 minutes and is obtainable, on free loan, by writing to the public relations department of the Federation, at the above address.

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ALL-PLASTICS PLUMBING

Polythene Pipe Connectors

With the introduction of polythene pipe fittings, known as Alkalite fittings and made in standard Alkathene, by Imperial Chemical Industries, Limited, Kynoch Works, Birmingham, it is now possible for the first time to install all-polythene pipework in cold-water plumbing systems. Hitherto, when polythene tubing has had to be joined, it has been necessary to use metal couplings—a disadvantage when the pipe-work is to be buried underground since it is then necessary to protect the fittings from corrosion. They are at present made in ½ in., ¾ in. and 1 in. nominal sizes for normal-gauge Alkathene, in the form of straight couplings, elbows, T-connectors, reducers and adaptors for joining Alkathene to metal piping. Later it is intended to introduce similar fittings in heavy-gauge material.

The joint, which is permanent and cannot be dismantled, is made by welding the polythene tube to the fitting. The end of the polythene tube is cut square and pushed into the fitting until it butts closely against a shoulder stop inside. Moulded into the Alkalite fittings are circular resistance elements leading through the fitting body to two external connector wires. Low-voltage current at moderate amperage, passed through the elements via the connector wires, produces sufficient heat to cause local melting of both tube and fitting, welding them into a homogeneous whole.

A well-charged 6 volt heavy-duty battery, used in conjunction with cable leads of the correct cross-section and resistance for each size of fitting, will provide the necessary current. The welding operation itself takes 15 to 30 seconds and is stopped by breaking the circuit when molten polythene escapes from the point of entry of the connector leads into the fitting. After leaving the joint to cool for a few minutes, the connector wires are snipped off.

The high coefficient expansion of Alkathene, and the close fit between tube and fitting, combine to ensure a reliable joint. Mechanically, the weld is made at the strongest point, making the joint air-tight and water-tight and with a tensile strength of the same order as the tube itself. Joints made this way have satisfactorily withstood stringent reversal and fatigue tests, and this type of fitting is being employed successfully in research work even under the searching demands of high-vacuum processes.

A further advantage is that the Alkalite method involves no manipulation of either the tube or the fitting. All that is necessary, beyond exercising care to follow instructions, is to place the tube in the fitting, attach the leads to battery and fitting and control the length of the welding cycle.

Using the procedure specified by the manufacturers, the critical factor is that of judging the correct welding time from visual inspection of the joint in the making, so that exactly the correct amount of heat is applied. For those who prefer to develop experience in the work before relying completely on the visual method, an special timer is available. This instrument, operating on the principle of bimetallic switches, is placed in the circuit between the battery and the Alkalite fitting. It is pre-set to the size of fitting involved and automatically controls the intensity of current and length of the welding cycle.

In Parliament

SCIENCE AND TECHNOLOGY AT THE UNIVERSITIES

Much has happened in the political and industrial fields since Parliament was adjourned for the summer recess on August 2 and, although a three-day meeting was held in mid-September to discuss the Suez-canal problem, there was, naturally, a considerable quantity of business awaiting the attention of the two Houses when sittings were resumed on October 23.

One of the matters brought forward on that day concerned the numbers of students taking science courses at universities in Great Britain and was raised by Mr. Ian Mikardo (Labour). He asked for information regarding university populations in 1938-39 and in four recent years. The reply of Mr. Harold Macmillan, the Chancellor of the Exchequer, showed that the total numbers of university students, both in pure science and in technology, had remained strikingly uniform throughout the period between 1951 and 1954.

In pure science, the numbers were 5,897 in 1938-39, rising to 12,010 in 1947-48 and to 13,916 in 1951-52; and declining slightly to 13,683 in 1952-53 and to 13,485 in 1953-54. In technology, the totals were 3,836 in 1938-39, 7,531 in 1947-48, 7,590 in 1951-52, 7,504 in 1952-53, and 7,439 in 1953-54. The numbers of first-year students during the same series of academic years were 1,883; 3,508; 3,487; 3,639; and 4,288, in pure science; and 1,391; 2,211; 1,775; 1,937 and 2,284, in technology. Mr. Macmillan's answer, which covered full-time students taking courses for a first degree at institutions in receipt of Treasury grants, also gave the numbers of second, third, fourth and fifth-year students engaged on these courses. He informed Mr. Mikardo that he was unable to divide the figures according to the separate subjects taken and stated that he had no corresponding information regarding diploma students of the numbers actually taking the degree and diploma examinations in these years.

GRANTS FOR RESEARCH

Another subject raised by Mr. Mikardo concerned the financial arrangements of the Department of Scientific and Industrial Research. He inquired of the Parliamentary Secretary to the Ministry of Works, as the representative of the Lord President of the Council, whether consideration had been given to the view of the Advisory Council to the Department that it would be necessary to revise the Department's grants to research associations, to take account of increases in prices.

Mr. J. R. Bevins replied that the five-year plan for the expansion of the Department's activities from 1954 to 1959 provided for a financial review in the event of major variations in prices. This had now taken place and, subject, of course, to the annual votes of the House, additional resources would be made available up to March, 1959, for grants to research associations and for other purposes.

As to the desirability of avoiding the reduction of other scientific grants in order to maintain the number of awards to post-graduate students, to which Mr. Mikardo also referred, Mr. Bevins said that the Department's receipts in respect of payments for its services would be greater than had previously been estimated. Accordingly, it would be possible to maintain the number of awards to post-graduate students and of grants for other scientific purposes during the financial year 1956-57.

NUCLEAR RESEARCH AT GENEVA

Mr. Bevins told Mr. Barnett Janner (Labour) that the European Organisation for Nuclear Research was set up under a convention of July, 1953, and that the United Kingdom's financial contribution to the Organisation's programme was, at present, 23·84 per cent., in accordance with a protocol annexed to that convention. The Government had contributed £1,161,000 during the period from October, 1954, when the Organisation came into being, up till the end of September last. A grant of £172,000 had previously been made to the interim organisation.

Progress in building the laboratory and its equipment was proceeding according to schedule, and details of the Organisation's programme and activities had been published in its first annual report. The total cost of the laboratory during the construction period, and including the cost of research work and maintenance, was now provisionally expected to amount to not less than £18 million, as against the original estimate of £10 million.

Prestwick Airport Improvements

Attention was drawn to improvements taking place at Prestwick Airport, by Sir Robert Boothby (Conservative), who desired to know what action was being taken to extend the runways there. In reply, Mr. Harold Watkinson, the Minister of Transport and Civil Aviation, said that the new subsidiary runway of 6,000 ft., which was opened last year, was being supplemented by 500 ft. of overrun at the southern end, and that that addition should be ready by the spring of next year. There were no plans for further extensions at the moment, but airline operators had been asked to provide early information on the performance and requirements of the big new jet aircraft which they hoped to introduce in a few years' time. Reliable information on this matter was essential to any decision on future ground requirements, whether at Prestwick or at any other aerodrome.

The Government, Mr. Watkinson stated, had agreed to the request of the British Overseas Airways Corporation for the purchase of fifteen Boeing 707 jet airliners, to be powered by Rolls-Royce Conway engines. The cost of the aircraft and initial spares would be about £44 million, of which £35 million would be in dollars.

Warship Designs

The Parliamentary Secretary to the Admiralty was asked by Mr. G. B. Finlay (Conservative) if he would introduce a system for the approval of designs for Her Majesty's ships similar to that in use in the United States Navy, under which detailed and final designs were prepared by the Bureau of Naval Construction. Mr. S. Wingfield Digby, Civil Lord of the Admiralty, replied that the question of whether any changes should be made in the present system of preparing designs for British warships, and the extent and nature of those changes, were among the matters now being studied by the committee under Sir Barclay Nihill.

Shipbuilding Orders

Replying to Mr. Paul Williams (Conservative), who asked about shipbuilding orders placed in Britain during the first nine months of this year, Mr. Digby said that orders for 67 merchant ships, of a total of 646,000 gross tons, were licensed for construction in shipyards on the North East Coast. During the same period, orders for 189 merchantmen, comprising 1,214,000 gross tons, were licensed for construction in United Kingdom shipyards as a whole.

Steel Industry Dispute

Lieut.-Colonel W. H. Bromley-Davenport (Conservative) wanted to know what action the Minister of Labour and National Service proposed to take on the recent report of the inquiry into the dispute in the steel industry, in view of the findings that the employers were rigid and intransigent and that the unions had acted in a precipitate and unconstitutional manner. Mr. Iain Macleod answered that on receipt of the report of the court of inquiry he had sent copies to both sides in the usual way, and that he did not consider that there was any need for him to take any further action. He added that the court's conclusion relating to an immediate increase in wages had been accepted by both sides and that the other conclusions were at present under consideration.

THE HUMAN ELEMENT

The road to a national wages policy—The Institute of Directors listens to the other side—Function of the N.J.A.C.—Growing labour problems in Germany—Boost for the mineworkers charter—Club protection or parental guidance for young people.

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This Fashionable 10 per cent.

The Amalgamated Engineering Union, the National Union of Railwaymen and the National Union of Bank Employees have all submitted claims for wage increases of 10 per cent. There may be others who will shortly do the same. Such a figure has, of course, a conclusive tidyness about it, as if those who made it had spared a thought for the wages clerks who will have to adjust the weekly wage sheets when the demand is accepted. But the fact is that there is as much a trend of fashion, and as little attention to facts and logic, in this matter as there is in women's millinery.

Signs are not lacking that the unions vie with each other to set the fashion, but once it has been set the others follow on hard behind. The coal miners have already taunted the engineering workers this year that they have extracted considerably poorer terms out of the engineering employers than the miners have got from the N.C.B. The leader of the Mineworkers did not hide his conviction that there is nothing like a nationalised industry for easing the work of trade union representatives. At the moment, the whole trade union world is poised waiting for the outcome of the demand of the provincial bus workers.

Such tactics, which are understandable enough, make a mockery of claims based on the performance of individual industries. The fact must be faced by the unions that if they negotiate by fashion they accept the substance, if not the form, of a national wages policy. That for them may be a sobering thought.

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The Discordant Voice of Mr. Cousins

Mr. Frank Cousins, general secretary of the Transport and General Workers' Union, was invited by the Institute of Directors to address their annual conference. The invitation drew five protests from members, including Lord Bracken, a director of several companies, including Union Corporation, A.E.I., and the *Financial Times*, who has resigned from the Institute. Mr. Cousins duly spoke, and drew much applause from the 5,000 delegates and their guests. The comments of the president of the Institute, Lord Chandos, are very apt. Regarding Lord Bracken's resignation—" a very old and dear friend of mine "—he said: " This is a country of free speech and I think it is as well to hear at first hand the different and discordant voices that make up a modern democracy with universal suffrage." In his view, Mr. Cousins " added something to our knowledge of the way trade union leaders are now thinking. A lot of his speech—not, of course, all—would find, I believe, ready acceptance among us."

Mr. Cousin's theme was " leadership " and he was quick to reject that of the Government, of any government. The Unions must establish a wages policy independently, to fit existing circumstances. Not only common justice but common prudence required that a new wage structure should be evolved for workers whose incomes had been seriously worsened by wage restraint, in relation to other workers, if industrial peace was not to be endangered. He denied that " wild men " were taking over in Transport House, or that the trade-union movement was entering a period of " ruthlessly militant " industrial relations. To take an independent line did not mean an anti-government line. The unions were willing to co-operate with employers to recover " our leadership in world trade and industry." British management, which in his view compared favourably with that elsewhere in the world, must move closer towards acceptance of " criticism at workshop level " and tackle their task in partnership with, rather than in opposition to, organised labour. More consultation, better communications, would go a long way towards building improved relationships.

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Parliament of Industry

Contracts of service for workers and the trends in short-time and overtime working were discussed last week at a meeting of the National Joint Advisory Council for Industry. Its chairman, Mr. Iain McLeod, Minister of Labour, told representatives of employers, nationalised industries and trade unions that he wanted to have informal discussions with both sides of industry before holding a formal meeting of the N.J.A.C. to consider the ideas put forward by the Government on service contracts (Human Element, October 19, " Recognition for Long Service "). The Council—which Mr. McLeod described as " the Parliament for Industry "—has an important task to perform in debating this question. Its quarterly meetings provide a good forum for the discussion of fundamental issues in labour-management relationships and, clearly, the Minister of Labour intends to use it as a sounding platform on major issues.

Restrictive practices are a case in point. They were not discussed at this meeting, but probably will be in January. So far, 41 industries have sent in their views—in answer to Mr. McLeod's request—and the others are to be sent a reminder.

Regarding service contracts, an official statement circulated after the meeting made clear that the Minister's initiative in this " did not in any way indicate a change in the attitude of the Government or himself towards the desirability of leaving the industrial negotiations entirely to the two sides of industry." In all matters, the Council's function is to remain strictly advisory and the Minister's part should be one of impartial leadership of lively discussion. This is a severe limitation on the N.J.A.C.'S " parliamentary " function, but a very healthy one.

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Restive German Labour

Unrest is growing in German heavy industry. The first challenge comes from the shipbuilding workers, in the traditionally militant area of Schleswig-Holstein. The Metal Workers Union called out 65,000 workers to back demands for better provisions for the welfare of their members. They want full pay during sickness up to six weeks, an extra 12*s.* 6*d.* per day bonus during annual holidays (on top of normal wages) and 18 working days of holidays instead of 12 as at present. These demands were agreed at the recent meeting of the trade unions in Hamburg; it only remained to select an area where union support was strong enough. The union membership at Schleswig-Holstein is said to be over 80 per cent. and a ballot showed that 88 per cent. of all engineering workers favoured a strike. Moreover, the challenge to the Government is a direct one: the State-owned Howaldt shipyards at Kiel are among those affected.

Trouble has been brewing for some time and it is becoming clear that the German workers will not tolerate much longer being paid less and treated worse than almost any other workers in Western Europe. The coal-mining industry is also the scene of strained relations between workers and employers, and the situation has deteriorated rapidly in the past few weeks. The chairman of the Miners' Union publicly described a levy of 5 *pfennige* per ton of coal, recently introduced by mineowners to provide a DM6 million " mutual assistance fund " a year, as " unheard-of provocation of the trade unions." Similar allegations have been made about steel-works in the Ruhr, who are said to have made an anti-strike pact providing for financial and other assistance to companies in case of strike. Though these are denied by the employers, there is little doubt that relations between them and the workers are deteriorating rapidly.

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Manoeuvres by the Miners

The Scottish miners have for long enjoyed their self-appointed role as leaders in militancy among the various areas of the National Mineworkers Union. True, they are Communist-dominated but that may not be of prime consideration. Behind it all lurks as much a Calvinistic urge to acquire disputatious authority as any overweening love of the Marxian dialectic. The latest foray from over the Border is a demand to the national executive of the N.U.M. to submit an immediate demand for higher wages. This has occurred just at the moment when the national body is trying to negotiate certain key objectives in the so-called miners' charter.

It is known that the N.C.B. is agreeable to conceding the demands under the charter provided that guarantees are given that productivity will not be impaired. The N.U.M. wishes to consolidate the weekly " bonus " shift into the basic wage: the N.C.B. is anxious that such a step should not encourage absenteeism. Other benefits set out under the " charter " have also to be discussed. These concern such matters as sick pay and pension improvements. Clearly, whatever formal titles are given to the national executive's ideas, the year 1956 for them is meant to be tidying-up operation on a number of outstand ng matters.

The N.C.B. is in a difficult position. It is well aware that its own need is to get more coal—and without raising costs unnecessarily in the process. It also knows that the N.U.M. can guarantee nothing, no matter what it may undertake to try to do. In the circumstances, however, it can hardly turn down the " charter " lest it evokes a demand for increased basic wages.

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Growth of the Youth Service

Addressing the Standing Conference of National Voluntary Youth Organisations recently, the Parliamentary Secretary to the Ministry of Education quoted some impressive figures about the voluntary effort which nowadays goes into such work. It is estimated that there are some 250,000 voluntary workers involved with a further 1,000 full-time leaders and 5,000 part-time workers. The Ministry granted about £100,000 to national voluntary organisations in the year 1955-56, in addition to the grant to the Central Council of Physical Recreation. A further £130,000 was offered in capital grants to individual clubs. Local authorities, too, spent £2-2½ million on this work towards which the Ministry made a 60 per cent. grant.

This growth of youth service work is an interesting phenomenon. It is happening in an age when inflation and indifference are making it increasingly difficult for the community to safeguard the survival of the elderly despite the fact that the population is growing older. The general attitude to voluntary work is also one of indifference. The age groups from which social workers come are on the whole too busy making ends meet, earning part-time income or working overtime, and leave social activities to the State. The middle classes, who have provided much of the voluntary labour, are no longer doing so, and the same forces which reduce volunteers for this sort of effort are also to some extent corroding family life. The question may yet have to be faced whether state-subsidised organised interest in youth is in fact a complicated, unconscious manoeuvre to find a " planned " alternative to parental responsibility.